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**Yeom**

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(54) **SEMICONDUCTOR DEVICES HAVING LINE TYPE ACTIVE REGIONS AND METHODS OF FABRICATING THE SAME**

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(73) Assignee: **Samsung Electronics Co., Ltd.** (KR)

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(22) Filed: **Jun. 17, 2009**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**  
**H01L 27/088** (2006.01)

(52) **U.S. Cl.** ..... **257/401**; 257/390; 257/394; 257/506; 257/E27.107

(58) **Field of Classification Search** ..... 257/390, 257/394, 401, 408, 506, 508, E27.107, E27.105; 438/176, 283, 589

See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

6,025,221 A 2/2000 Brown

6,297,129 B2	10/2001	Tran et al.	
6,362,501 B1	3/2002	Kim	
2005/0077560 A1*	4/2005	Shiratake	257/296
2005/0136616 A1	6/2005	Cho et al.	
2005/0173744 A1	8/2005	Kim et al.	
2005/0173759 A1*	8/2005	Kim et al.	257/331

**FOREIGN PATENT DOCUMENTS**

KR	10-2000-0074103 A	12/2000
KR	10-2004-0008424 A	1/2004
KR	10-2005-0017872 A	2/2005

**OTHER PUBLICATIONS**

Application and Prosecution history of U.S. Appl. No. 11/353,494, filed Feb. 14, 2006, by Kye-Hee Yeom, Entitled "Semiconductor Devices Having Line Type Active Regions and Methods of Fabricating the Same", which is stored in the United States Patent and Trademark Office (USPTO) Image File Wrapper (IFW) System.

\* cited by examiner

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(57) **ABSTRACT**

In a semiconductor device having line type active regions and a method of fabricating the semiconductor device, the semiconductor device includes a device isolation layer which defines the line type active regions in a semiconductor substrate. Gate electrodes which are parallel to each other and intersect the line type active regions are disposed over the semiconductor substrate. Here, the gate electrodes include both a device gate electrode and a recessed device isolation gate electrode. Alternatively, each of the gate electrodes is constituted of a device gate electrode and a plan type device isolation gate electrode, and a width of the plan type device isolation gate electrode greater than a width of the device gate electrode.

**18 Claims, 24 Drawing Sheets**

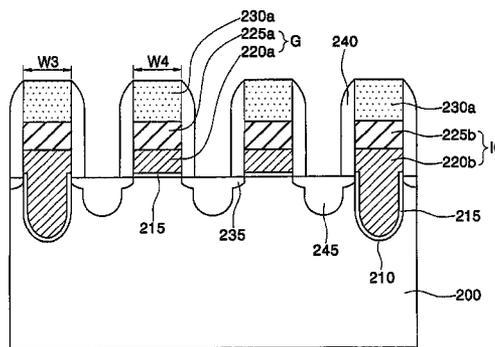
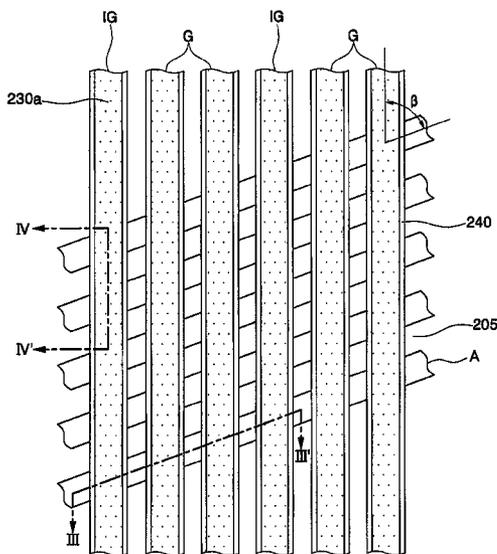


FIG. 1A

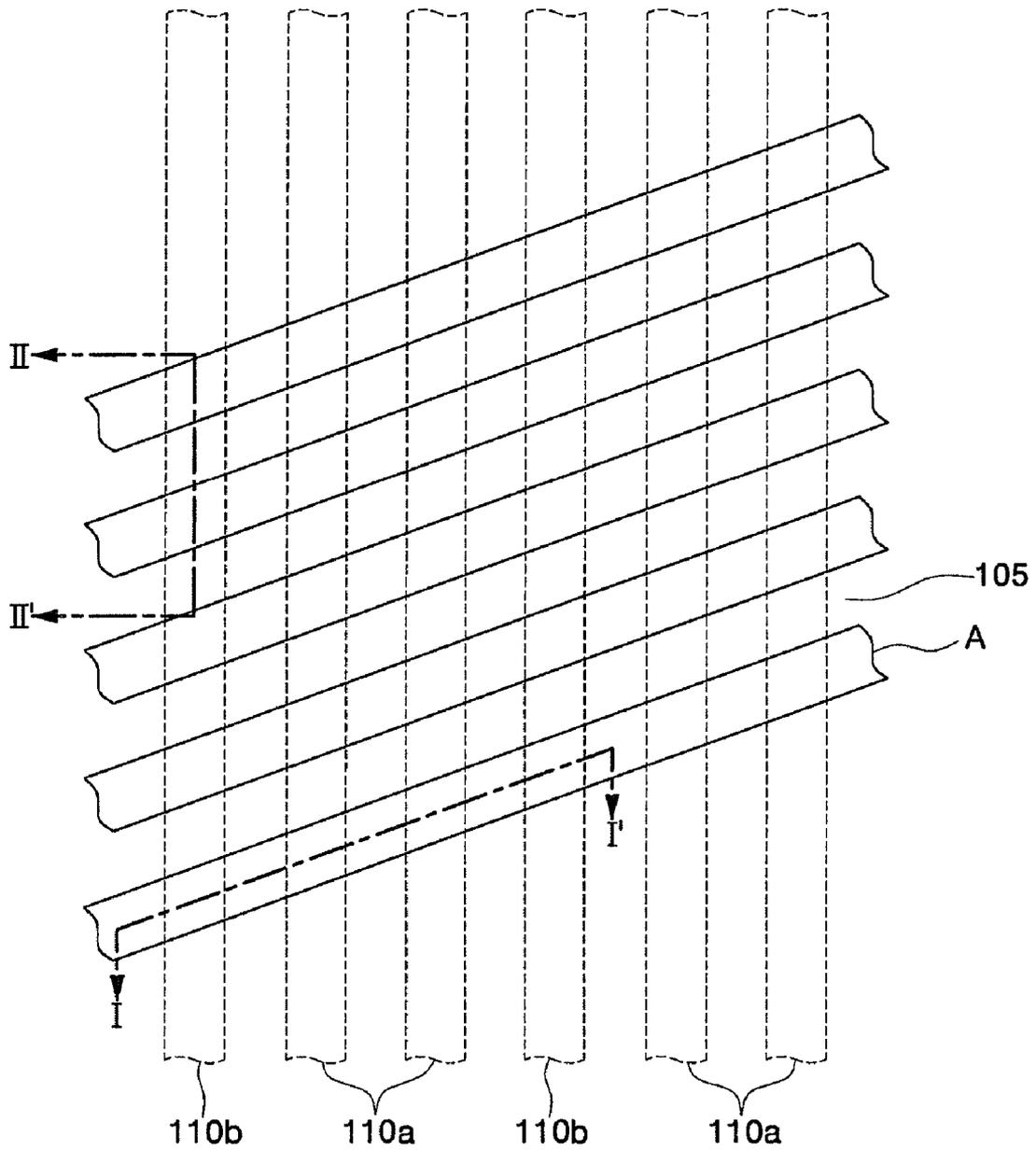




FIG. 2A

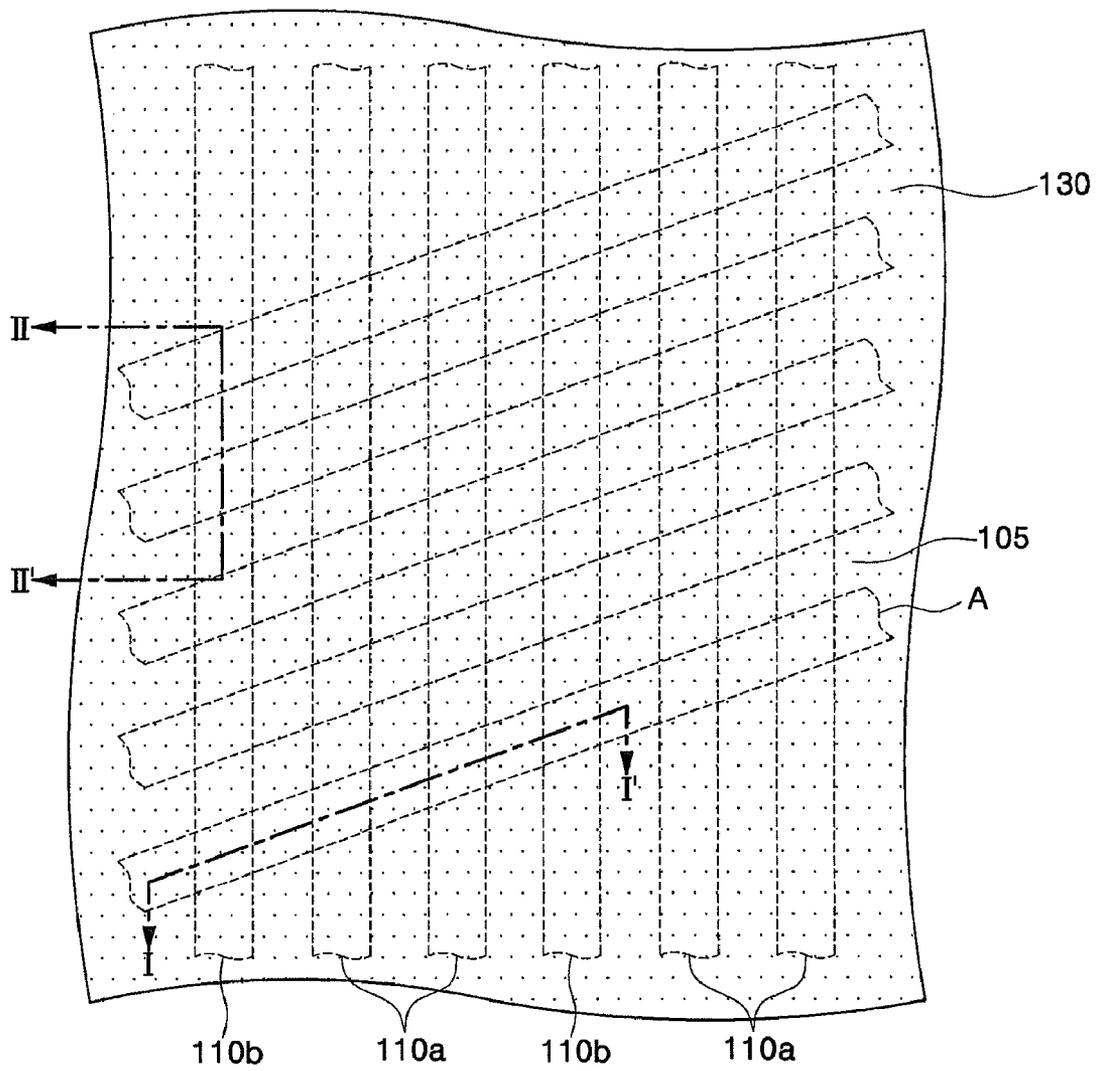


FIG. 2B

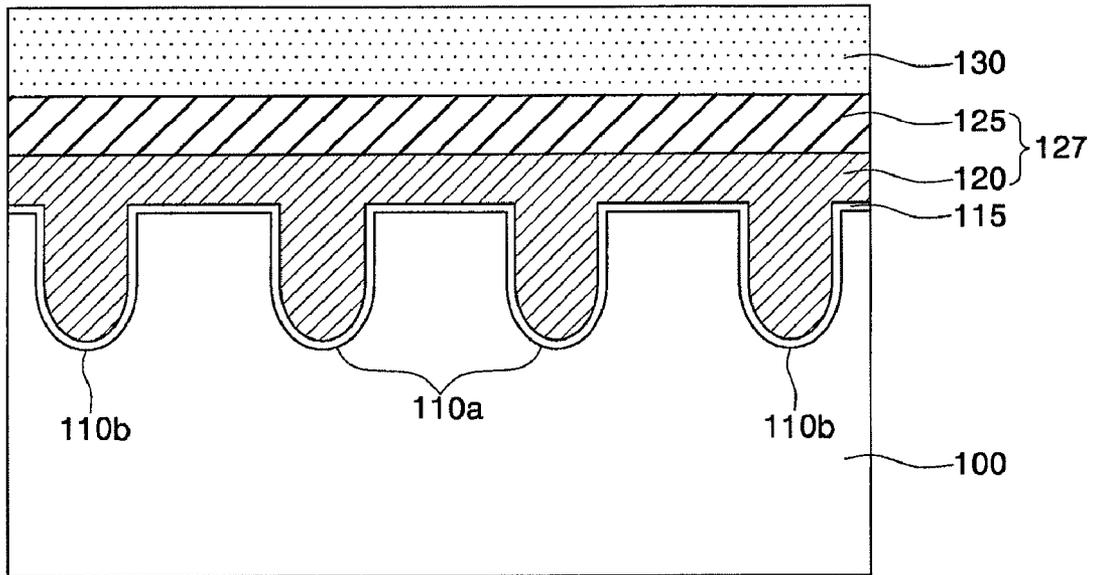


FIG. 2C

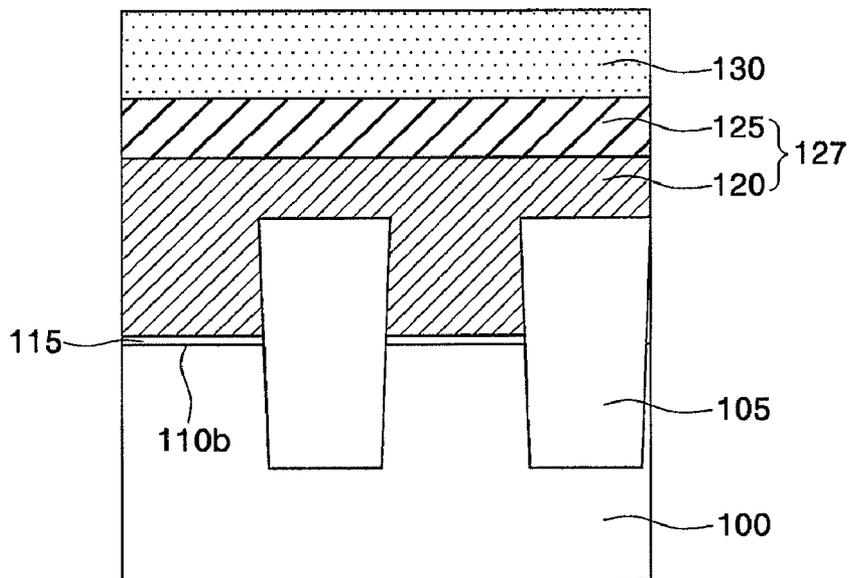


FIG. 3A

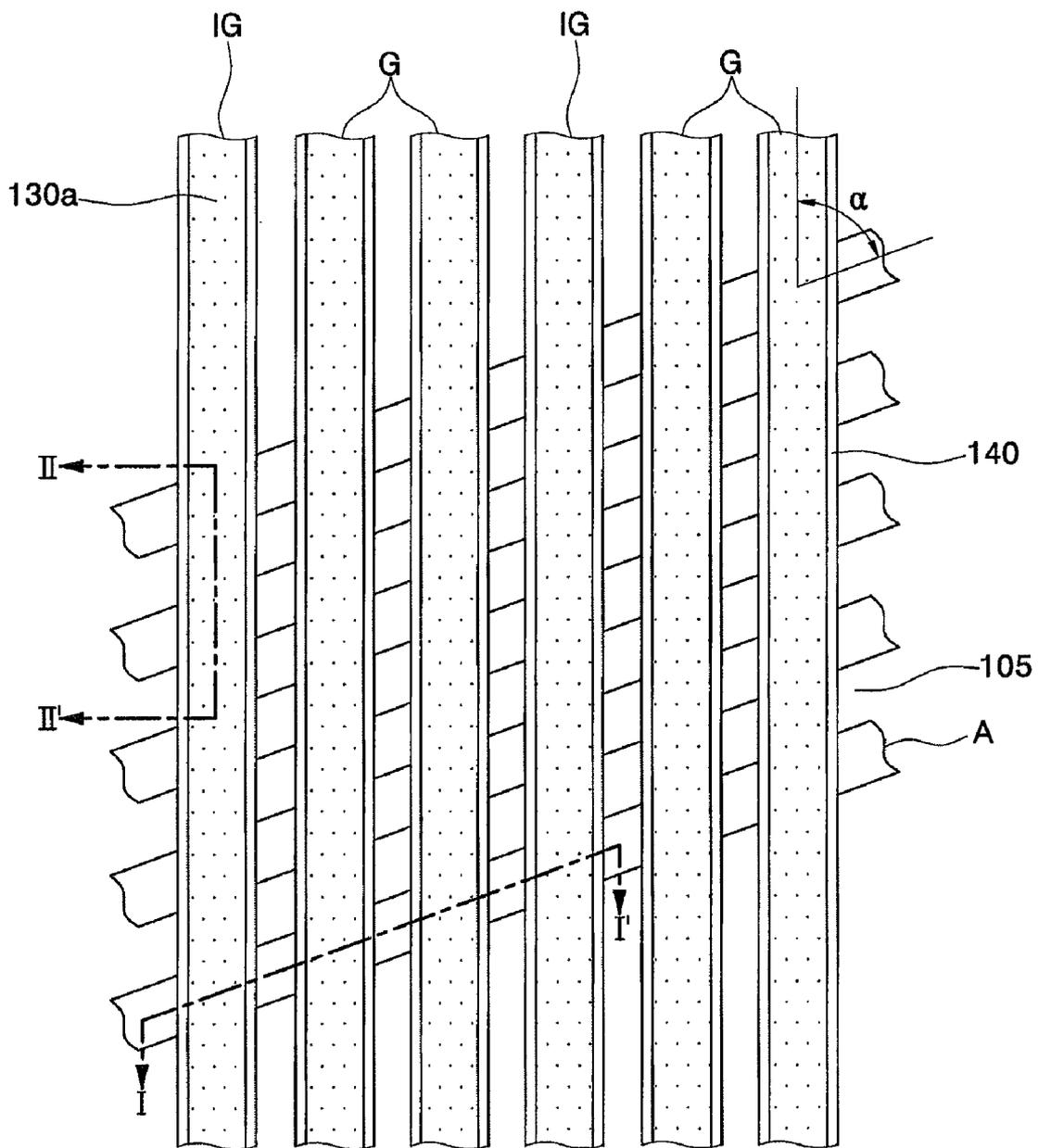


FIG. 3B

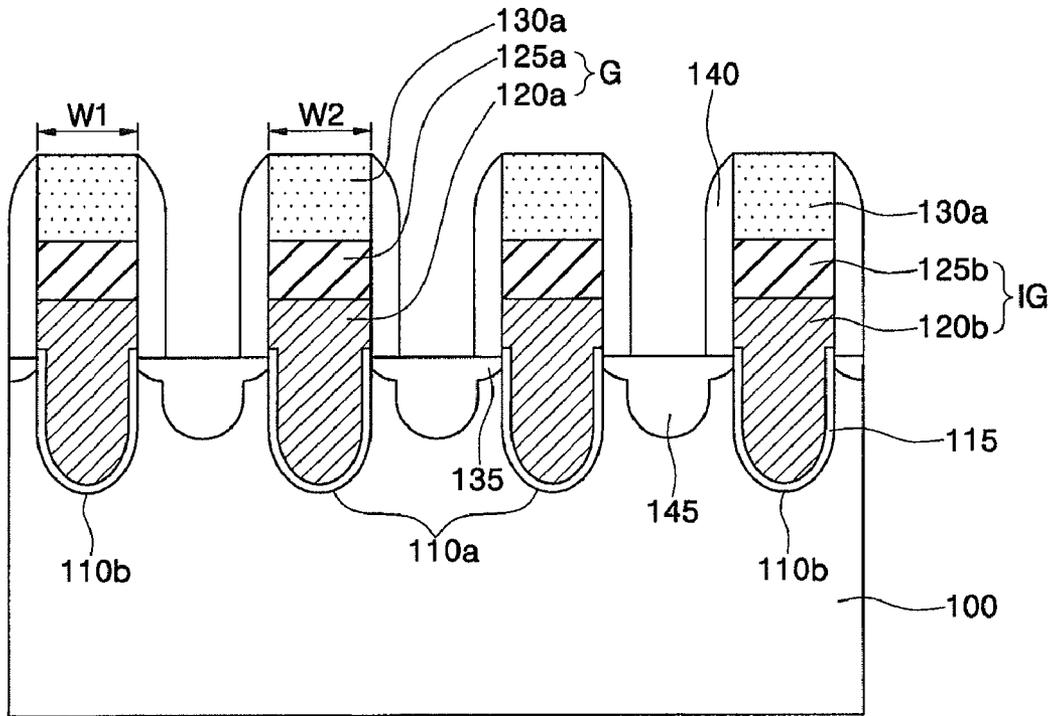


FIG. 3C

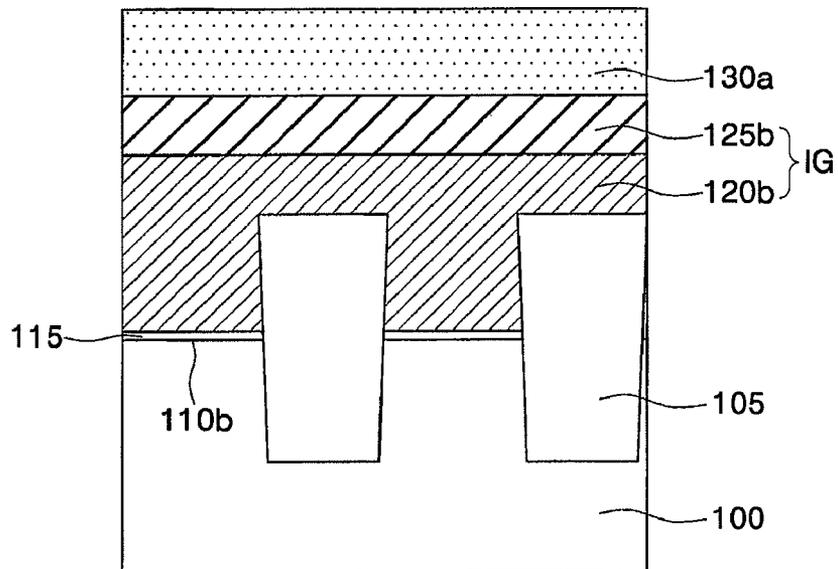


FIG. 4A

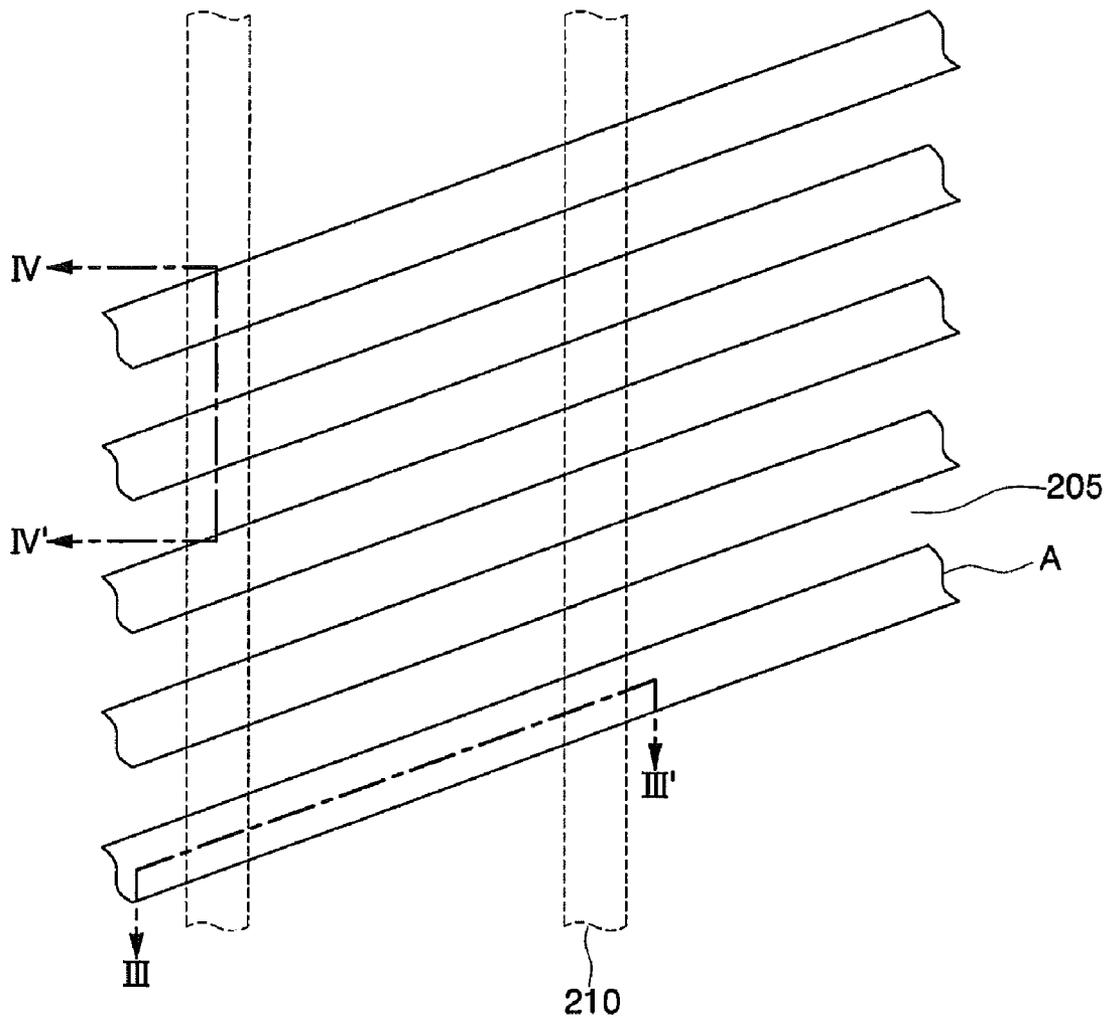


FIG. 4B

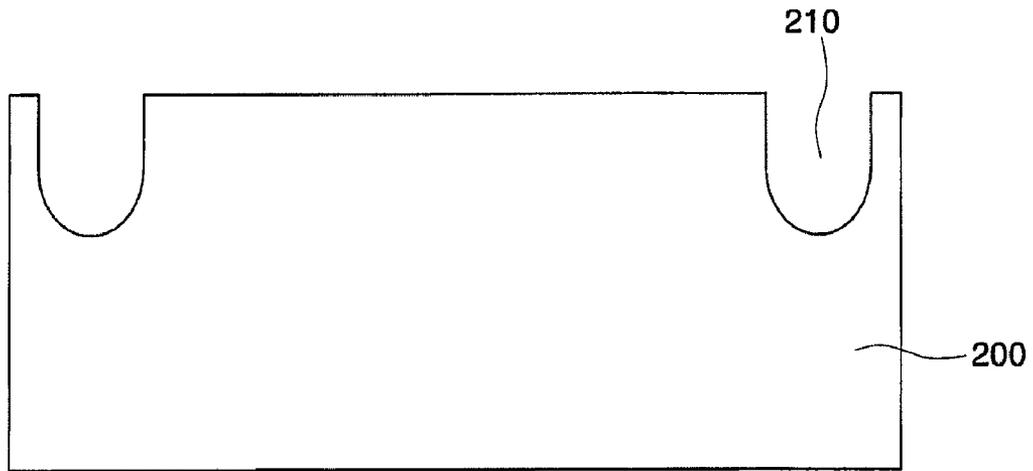


FIG. 4C

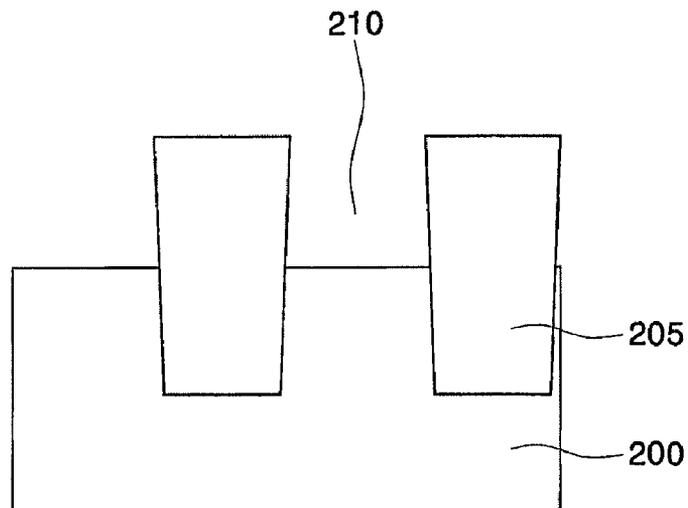


FIG. 5A

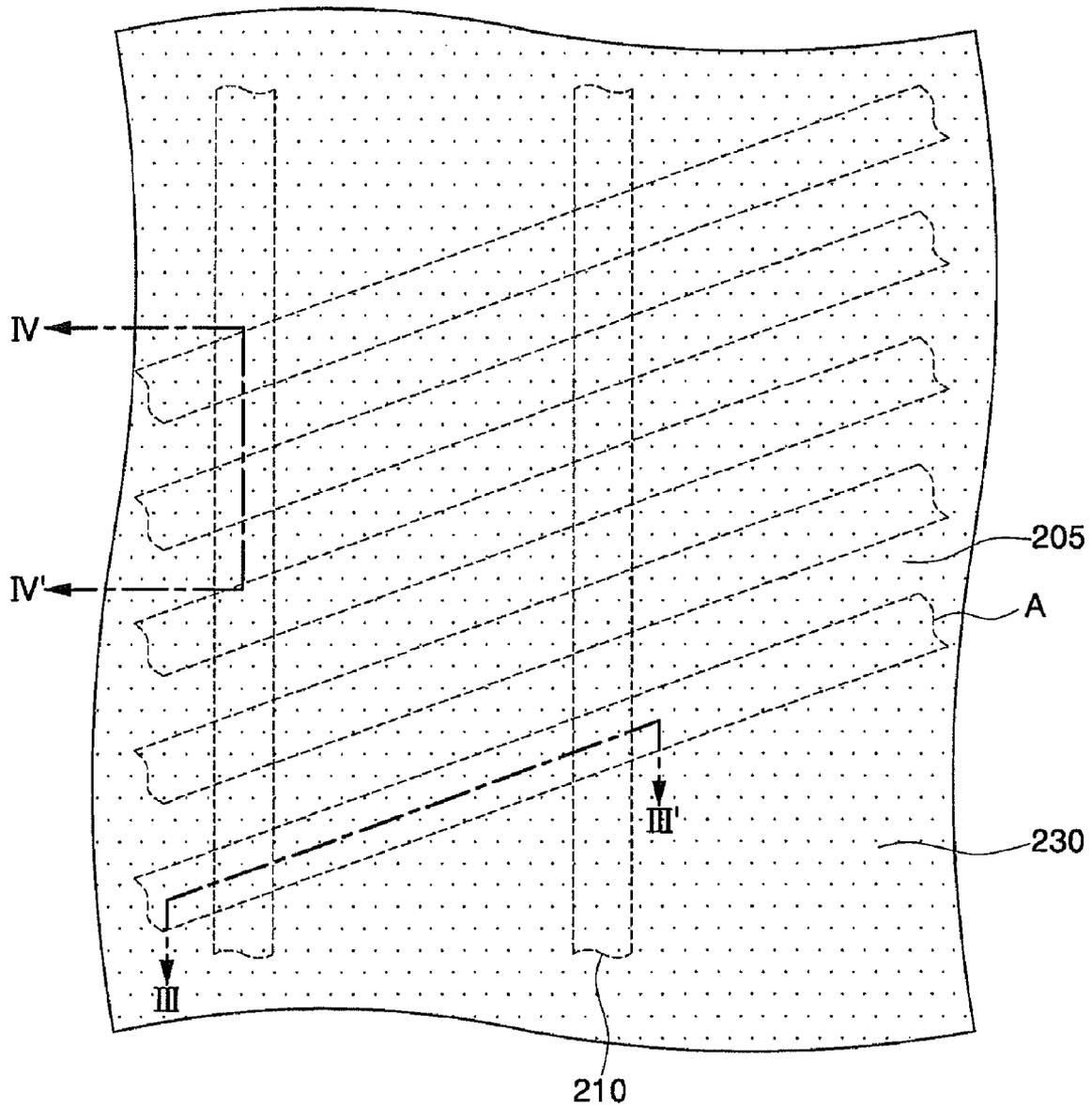


FIG. 5B

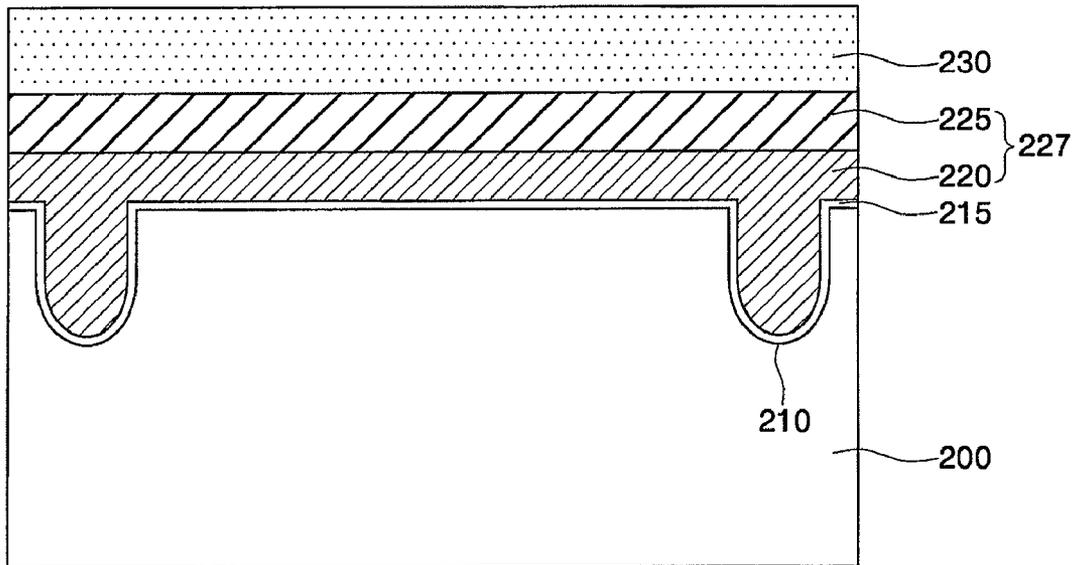


FIG. 5C

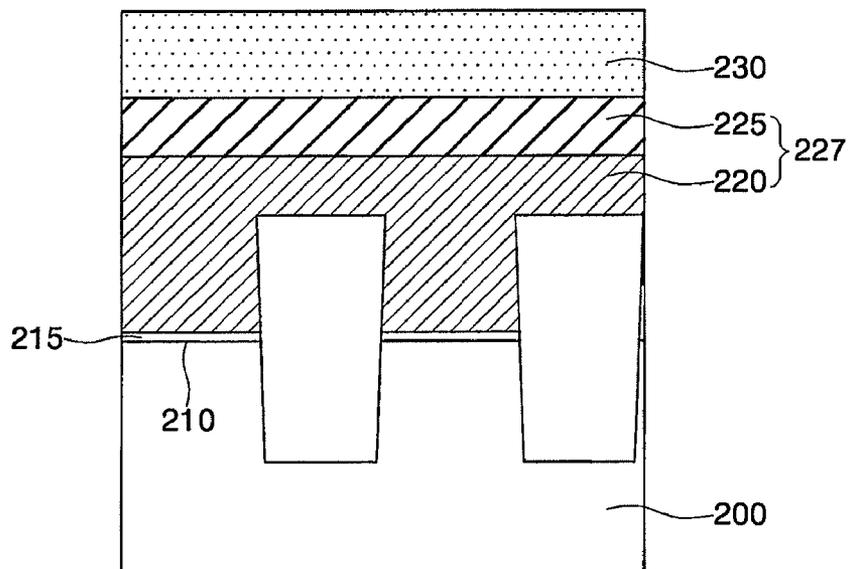


FIG. 6A

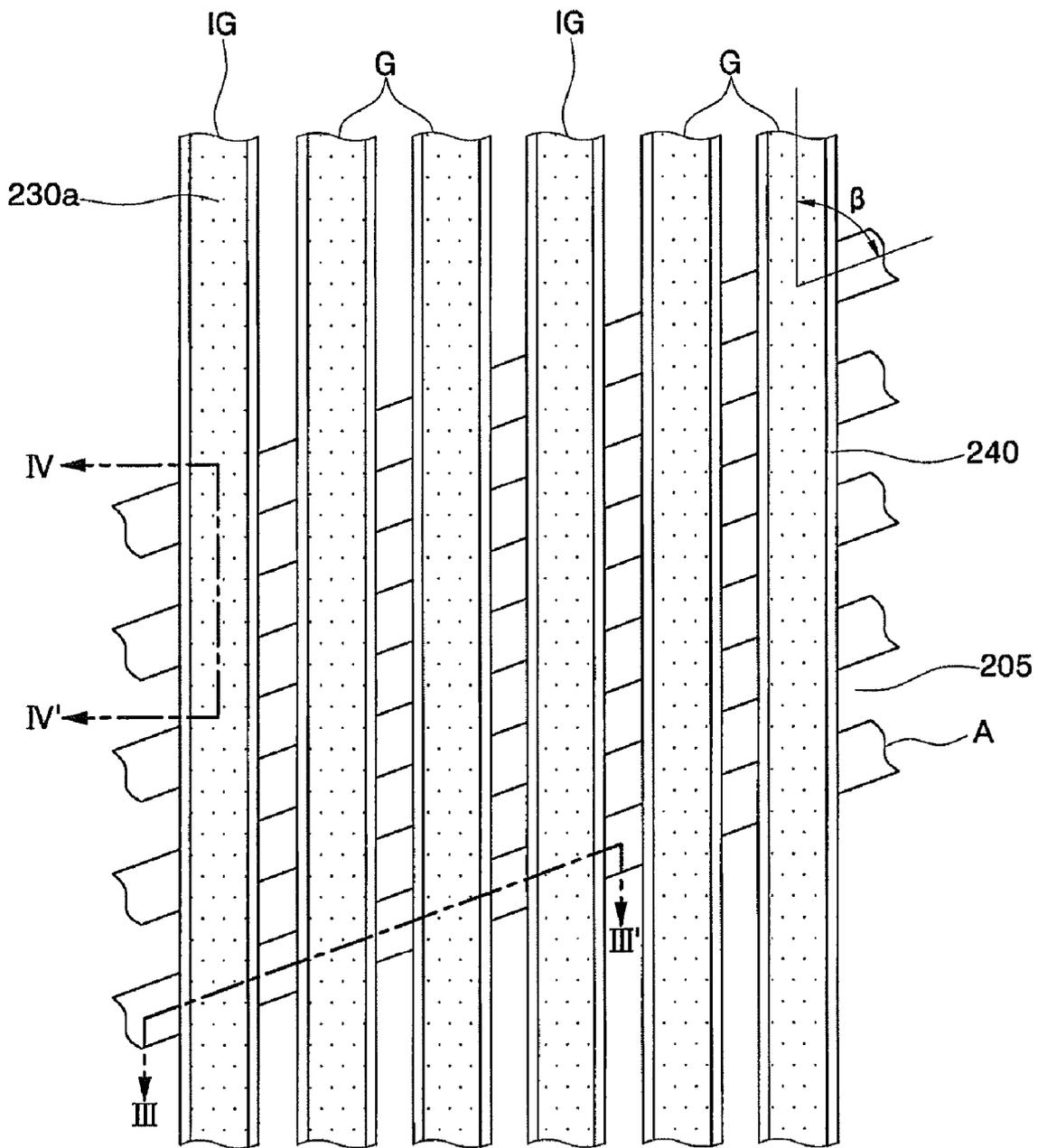


FIG. 6B

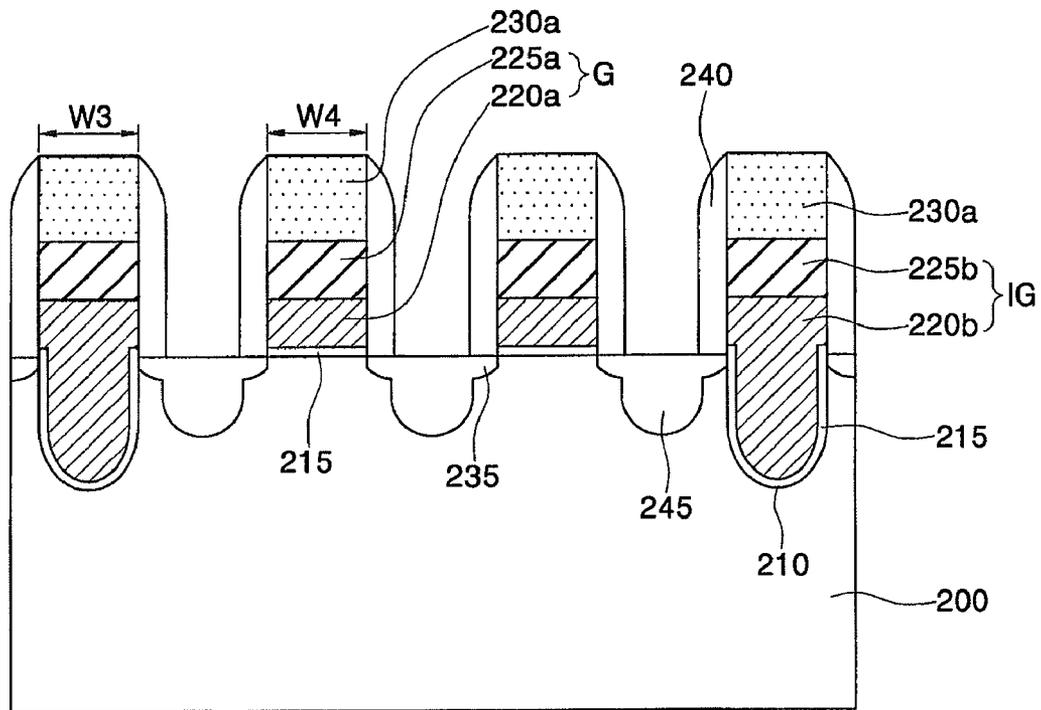


FIG. 6C

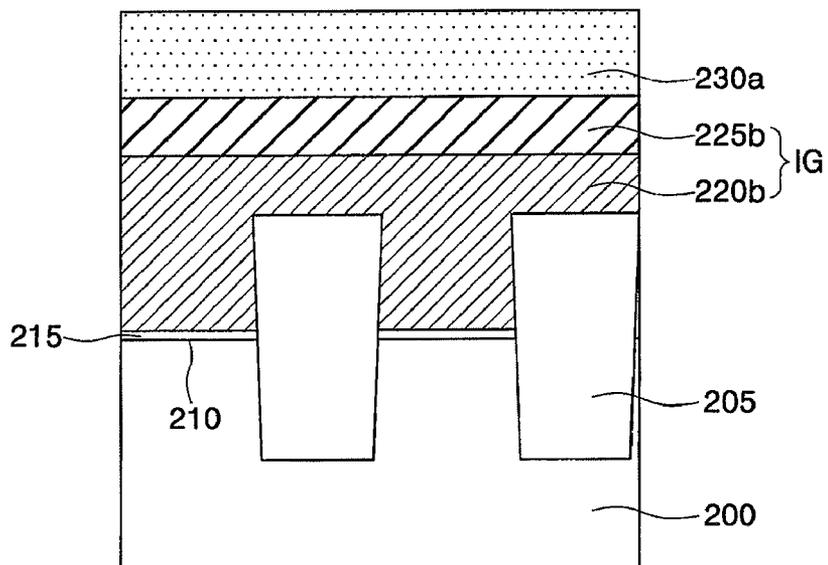


FIG. 7A

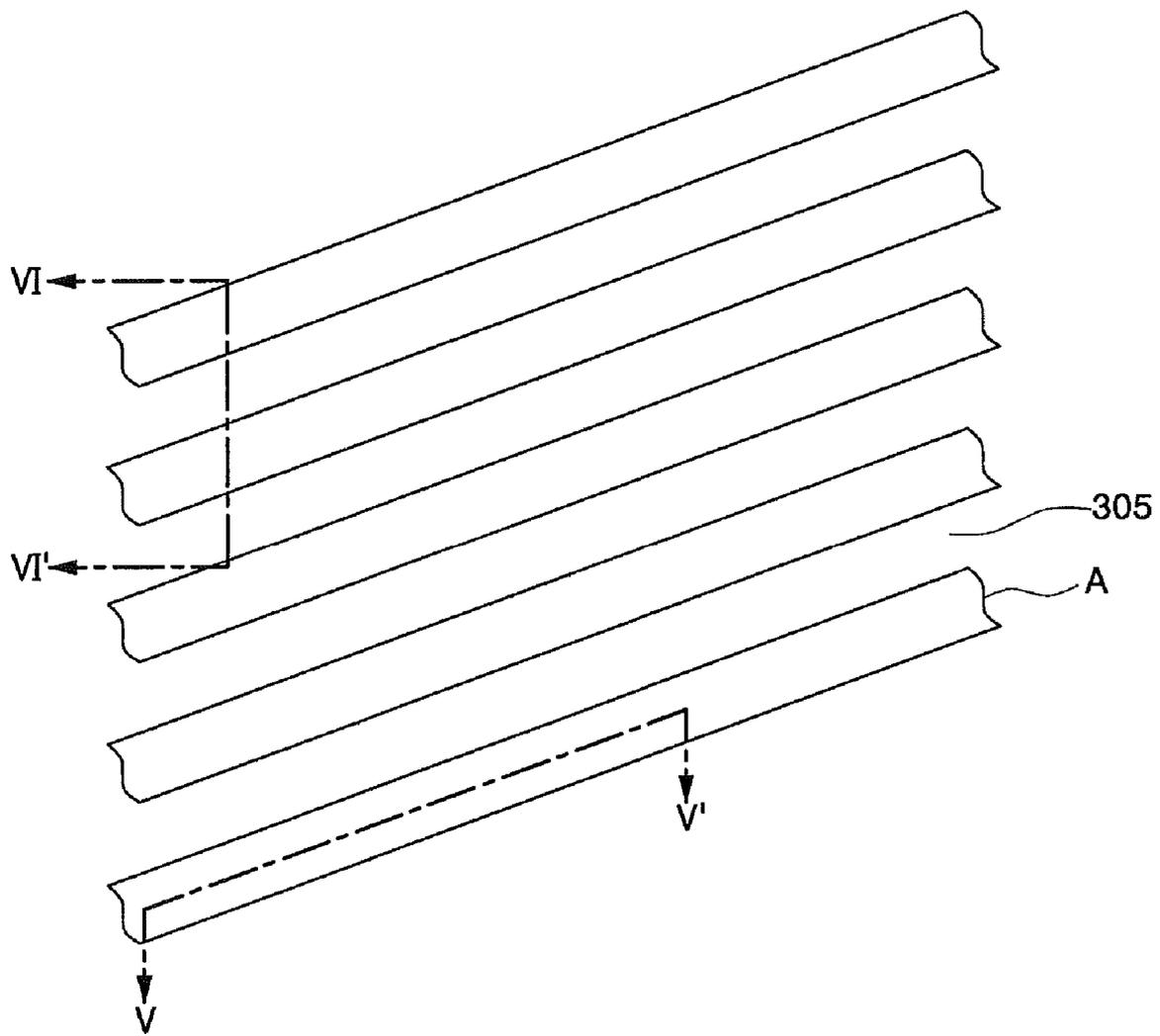


FIG. 7B

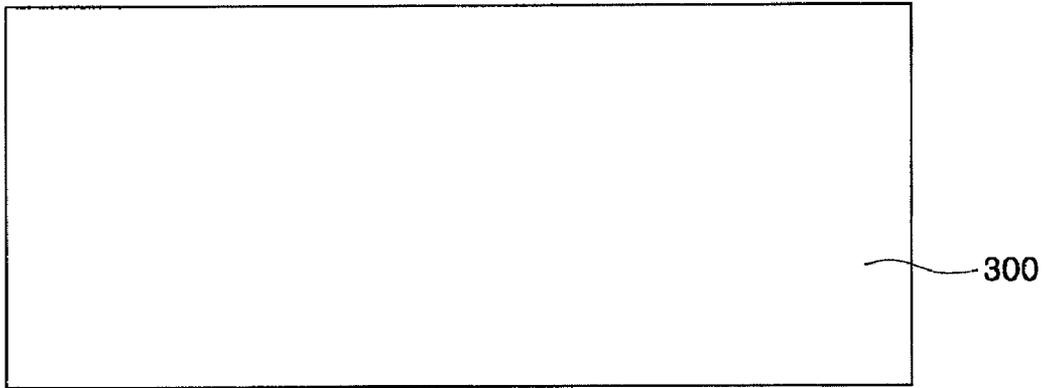


FIG. 7C

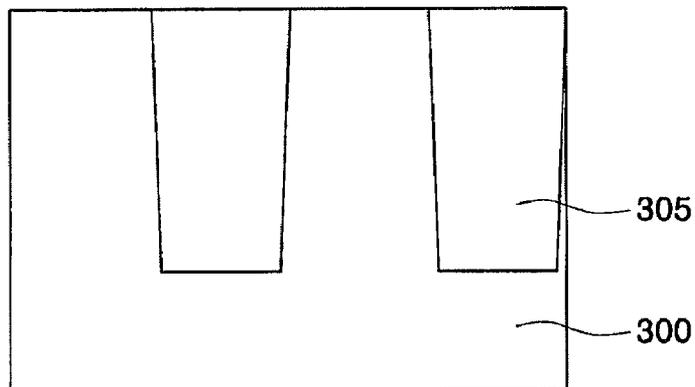


FIG. 8A

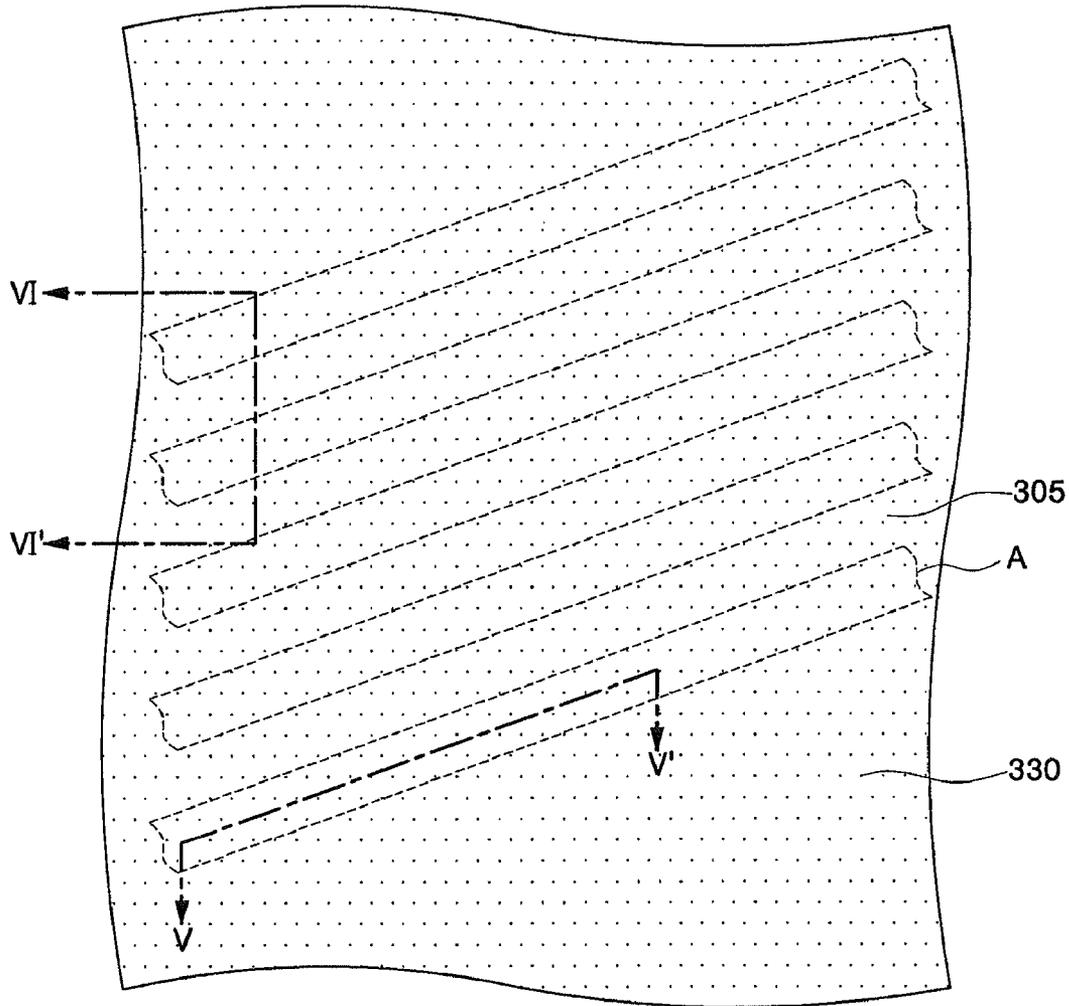


FIG. 8B

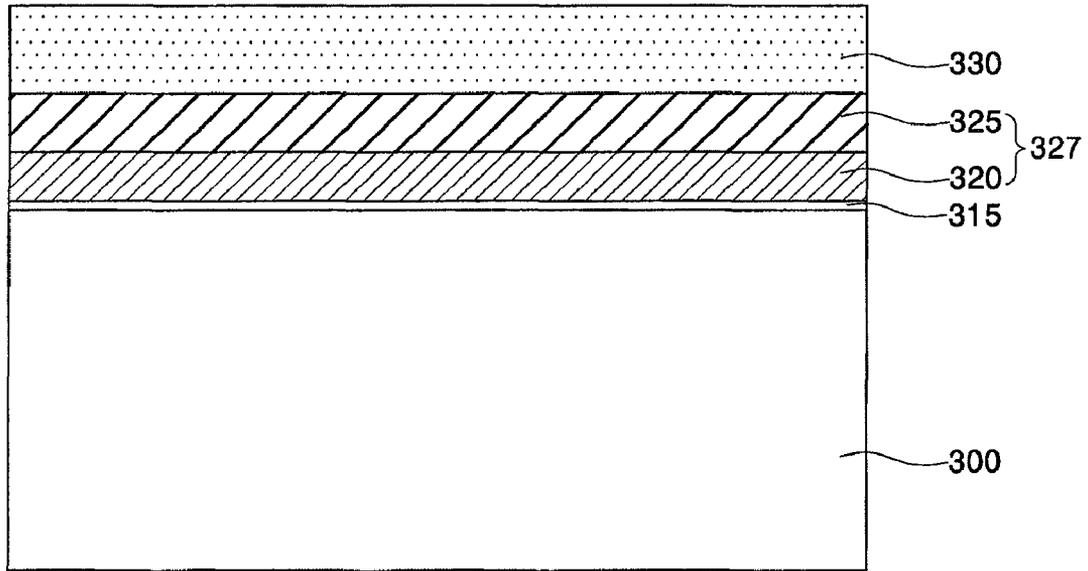


FIG. 8C

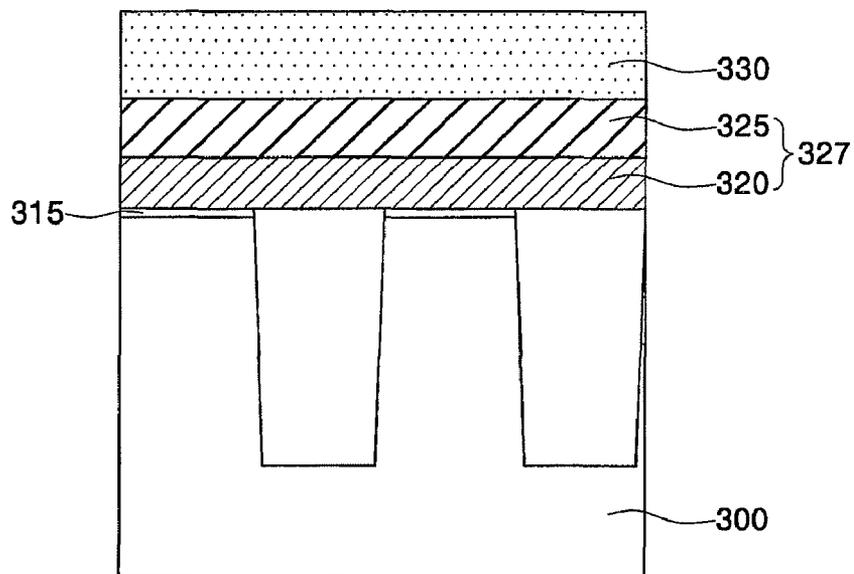


FIG. 9A

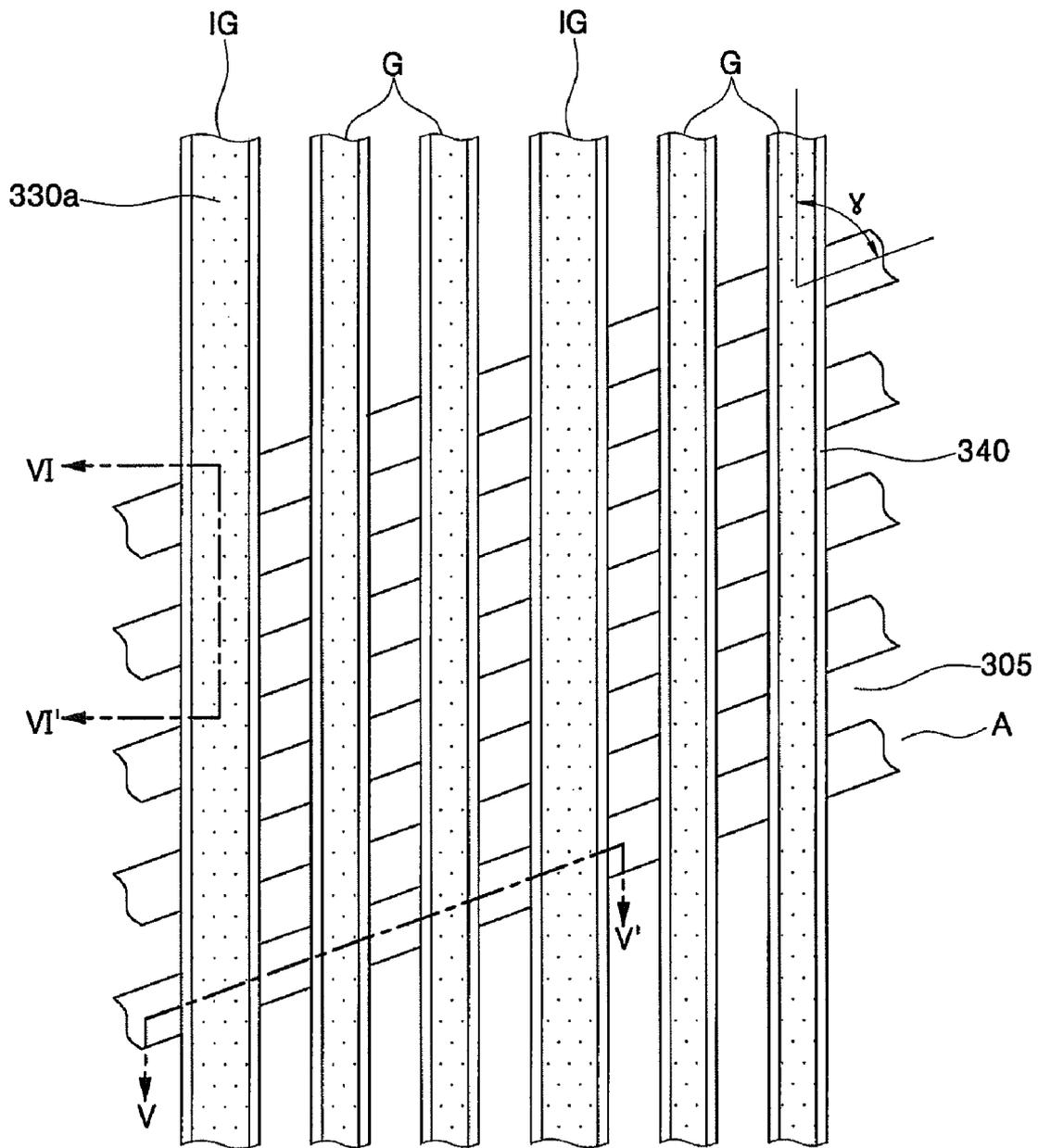


FIG. 9B

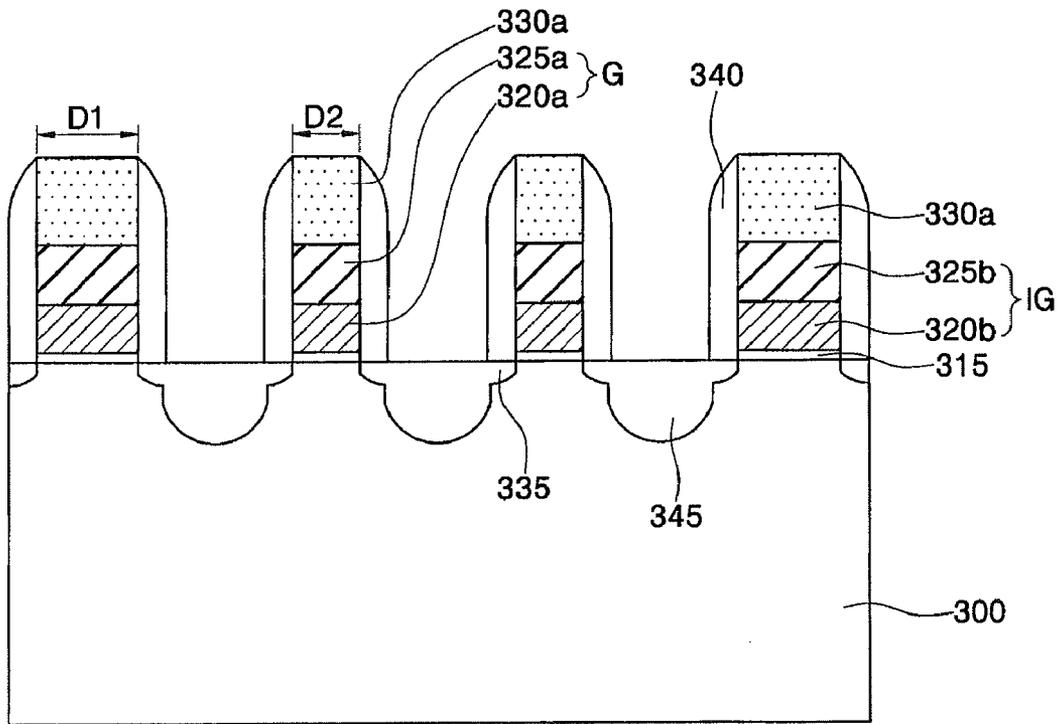


FIG. 9C

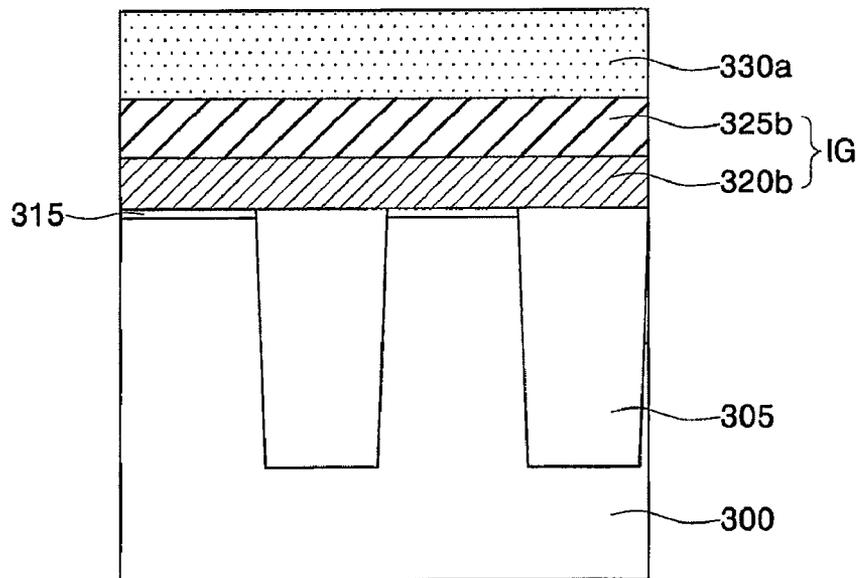


FIG. 10A

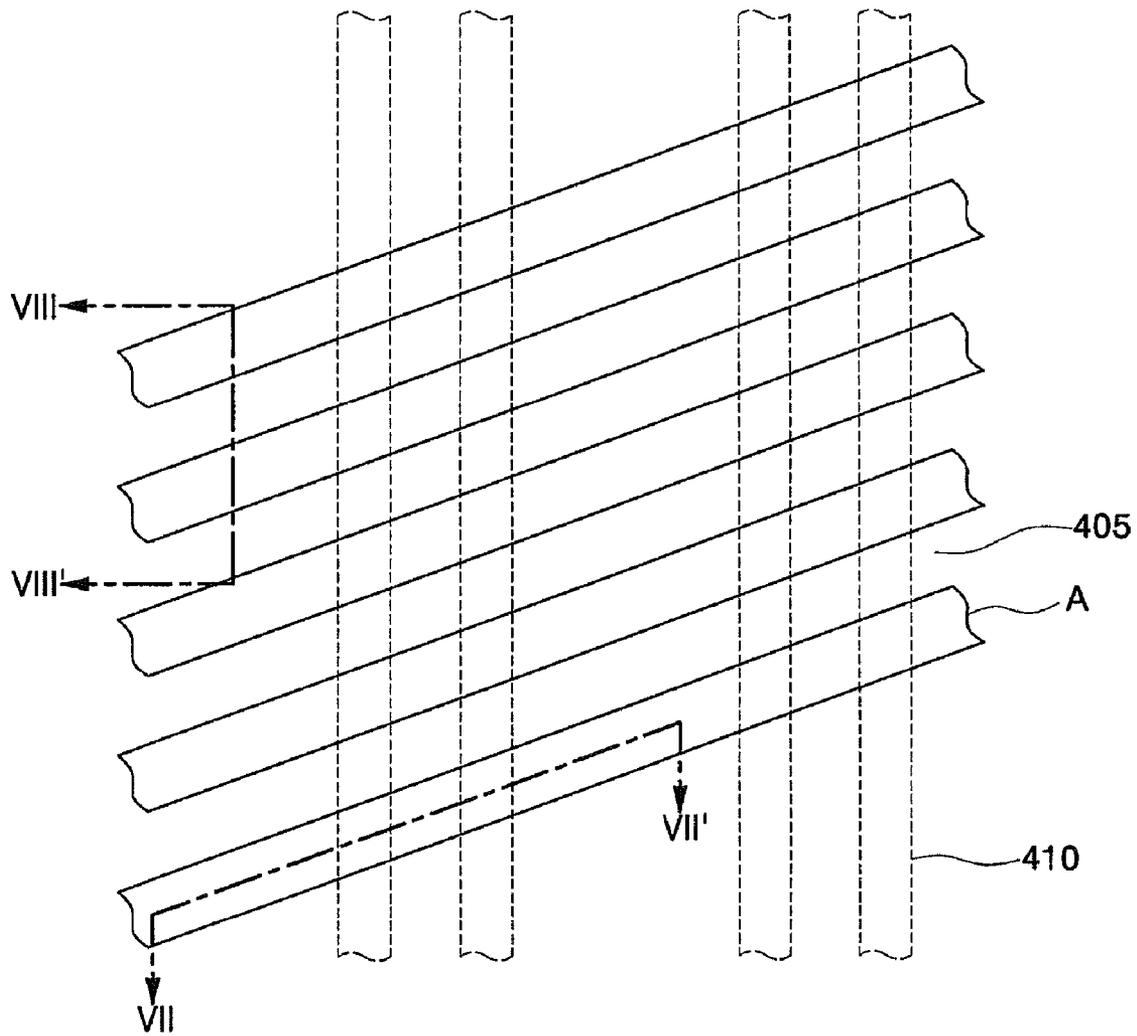


FIG. 10B

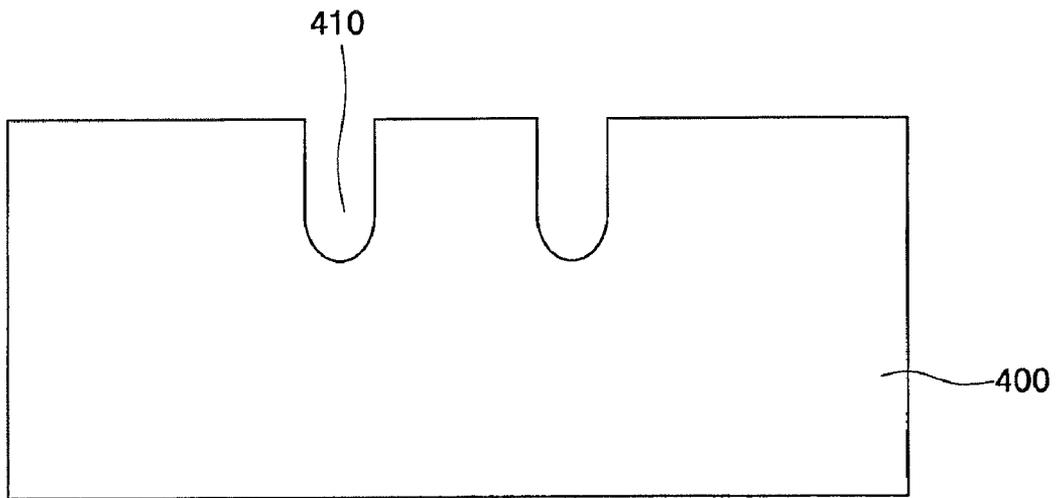


FIG. 10C

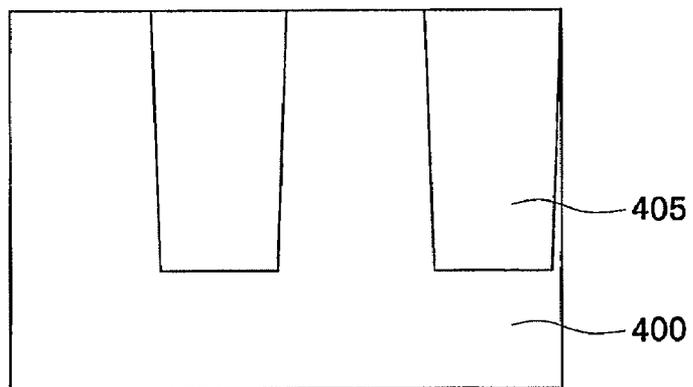


FIG. 11A

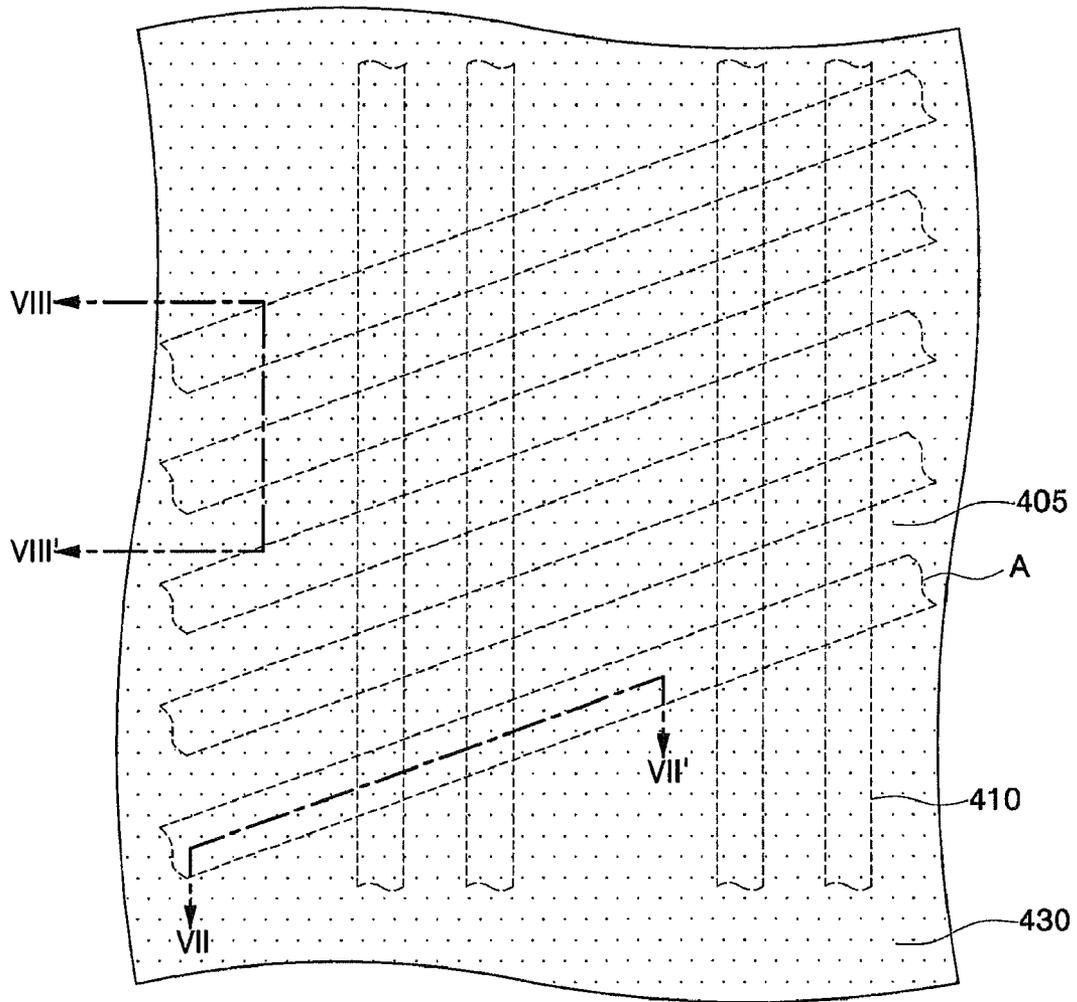


FIG. 11B

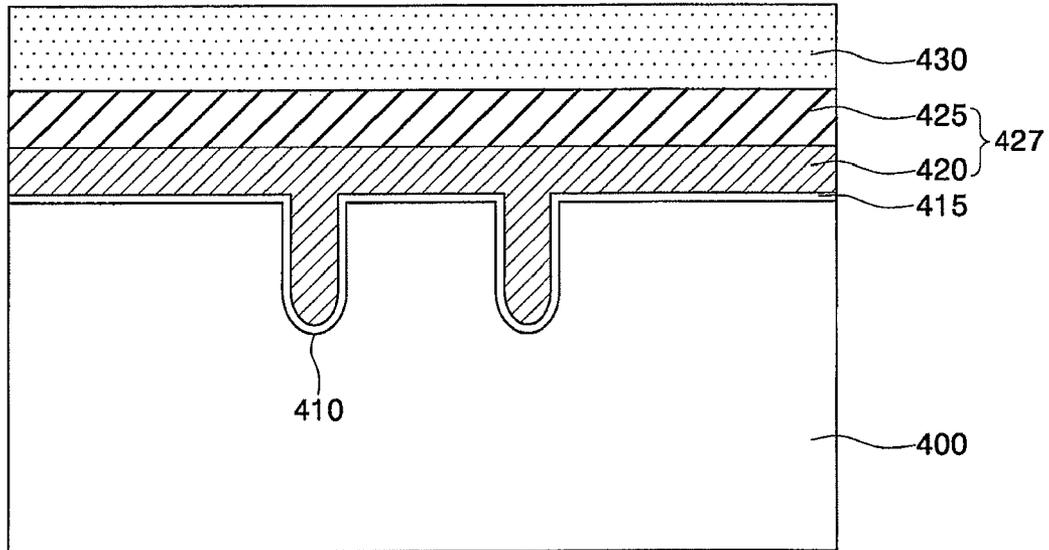


FIG. 11C

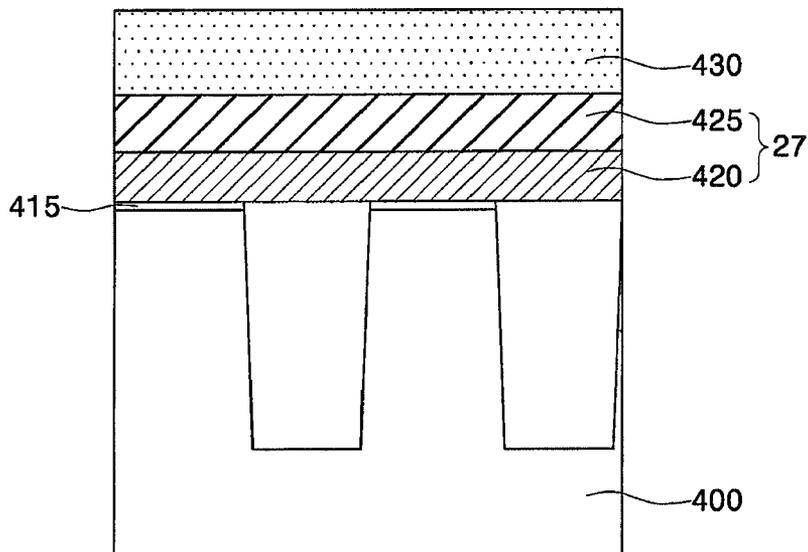


FIG. 12A

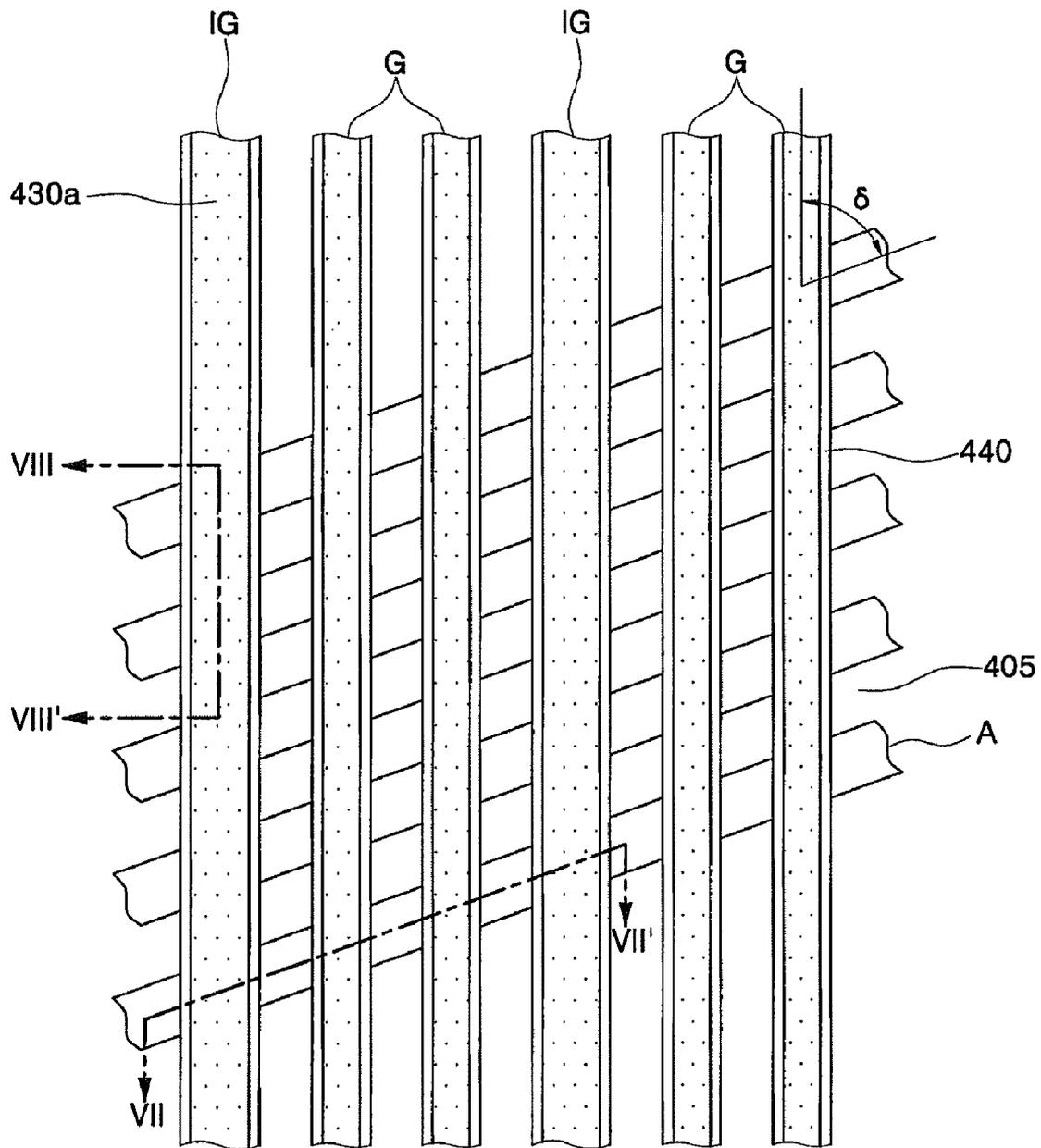


FIG. 12B

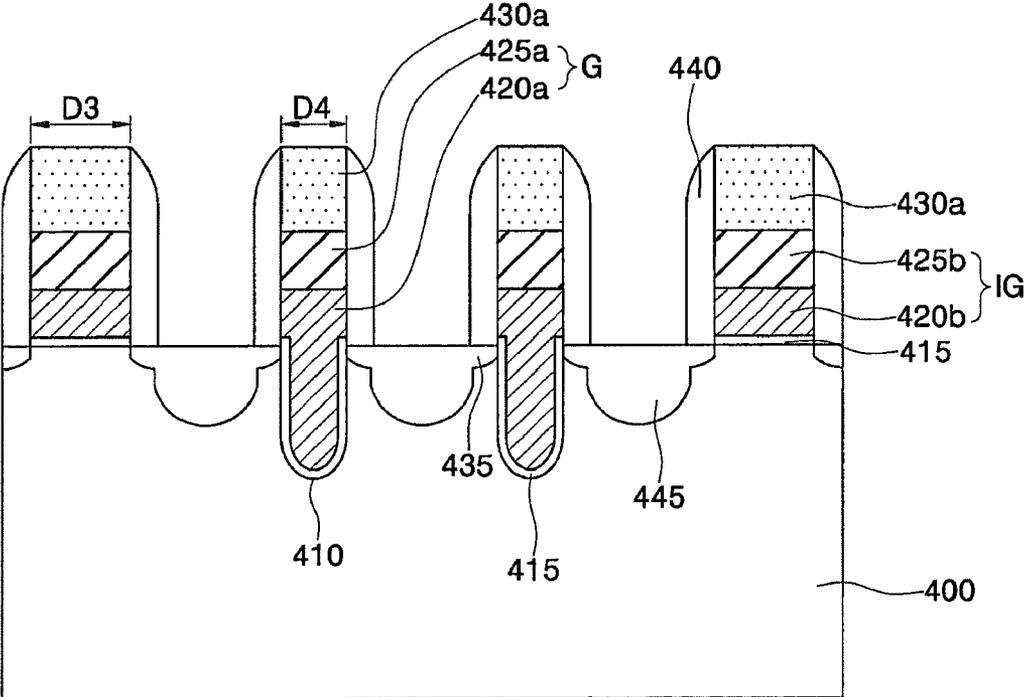
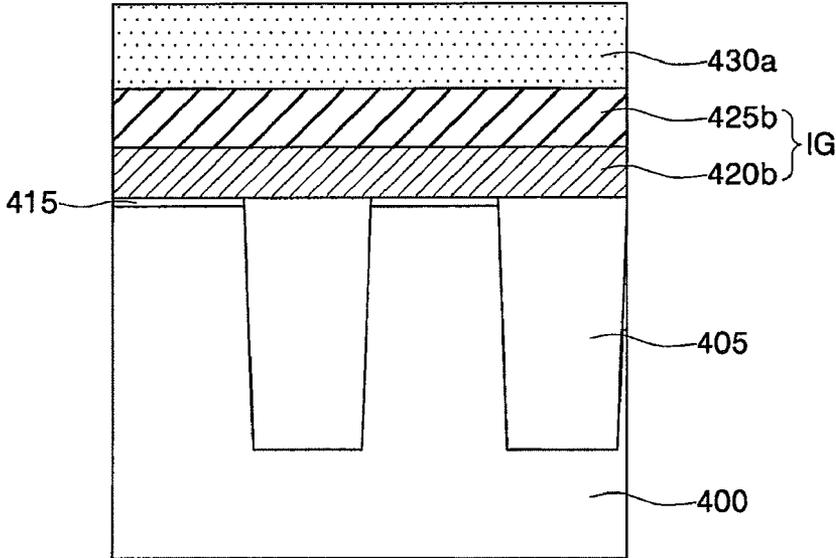


FIG. 12C



## SEMICONDUCTOR DEVICES HAVING LINE TYPE ACTIVE REGIONS AND METHODS OF FABRICATING THE SAME

### CROSS-REFERENCE TO RELATED PATENT APPLICATION

This application is a divisional of U.S. application Ser. No. 11/353,494, filed on Feb. 14, 2006, which relies for priority upon Korean Patent Application No. 10-2005-0017872, filed Mar. 3, 2005, the disclosure of which is hereby incorporated herein by reference in its entirety.

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention relates to semiconductor devices and methods of fabricating the same, and more particularly, to semiconductor devices having line type active regions and methods of fabricating the same.

#### 2. Description of Related Art

As the integration degree of semiconductor memory devices such as DRAM devices continues to increase, the area available to memory devices integrated on a wafer is reduced, and the areas occupied by transistors and capacitors are also reduced according to a predetermined ratio. A basic component of semiconductor memory devices is the memory cell, in which a single bit of information can be stored. The DRAM device comprises a plurality of cells, each having one transistor and one capacitor, and peripheral circuits which can perform read and write operations in order to store information in the cells and retrieve information from the cells.

A conventional DRAM cell array has island type active regions. As the integration degree of the memory device increases, areas of the island type active regions accommodating individual transistors are also reduced. Therefore, although a mask design may have the shape of a rectangle, the active regions actually defined on a substrate have a rounded shape, approximately the shape of a circle due to technical limitations in the photolithography and etching processes. In addition, as areas of interconnections and capacitors connected to the island type active regions become further reduced, misalignment such as over-contact occurs, causing a reduction in device fabrication yield and device reliability. In addition, as the active regions are defined with the island shape, areas occupied by device isolation regions which are required for insulation between the active regions are necessarily relatively large in the substrate, so that there is a limitation in the integration density of the devices.

Therefore, there has been proposed a method of electrically isolating the cells by forming line type active regions, forming device gates and device isolation gates to intersect the line type active regions, and applying a voltage so as to prevent occurrence of current channels from forming under the device isolation gate. However, the method of isolating the devices by using the device isolation gates cannot effectively perform device isolation function in comparison to the method using the island type active regions. In addition, as the integration degree increases, a width of the gate is reduced, so that a device isolation gate function cannot be efficiently performed.

### SUMMARY OF THE INVENTION

The present invention provides a semiconductor device suitable for using line type active regions and improving

device isolation gate characteristics and a method of fabricating the same in manner that addresses the stated limitations in the conventional approaches.

According to an aspect of the present invention, there is provided a semiconductor device having line type active regions. The semiconductor device comprises a device isolation layer which defines the line type active regions in a semiconductor substrate. Gate electrodes which are parallel to each other and intersect the line type active regions are disposed over the semiconductor substrate. Here, the gate electrodes include both a device gate electrode and a recessed device isolation gate electrode.

Preferably, the device gate electrode is a plan type device gate electrode or a recessed device gate electrode. A width of the recessed device isolation gate electrode is equal to or larger than a width of the device gate electrode.

Preferably, an off bias is applied to the recessed device isolation gate electrode during operation to provide a device isolation function.

An intersection angle of the line type active regions and the gate electrodes may be in a range of 20° to 90°.

According to another aspect of the present invention, there is provided a semiconductor device having line type active regions. The semiconductor device comprises a device isolation layer which defines the line type active regions in a semiconductor substrate. Gate electrodes which are parallel to each other and intersect the line type active regions are disposed over the semiconductor substrate. Here, the gate electrodes include both a device gate electrode and a plan type device isolation gate electrode, and a width of the plan type device isolation gate electrode is disposed to be greater than a width of the device gate electrode.

The device gate electrode may be a plan type device gate electrode or a recessed device gate electrode.

Preferably, an off bias is applied to the plan type device isolation gate electrode during operation to provide a device isolation function.

An intersection angle of the line type active regions and the gate electrodes may be in a range of 20° to 90°.

According to another aspect of the present invention, there is provided a method of fabricating semiconductor device having line type active regions. The method comprises a step of forming a device isolation layer which defines the line type active regions in a semiconductor substrate, wherein the active regions are formed to have a line type structure. Device gate channel trenches and device isolation gate channel trenches which are parallel to each other and intersect the line type active regions are formed in the semiconductor substrate. A conformal gate insulating layer is formed on inner surfaces of the device gate channel trenches and the device isolation gate channel trenches. Recessed device gate electrodes filling the device gate channel trenches and recessed device isolation gate electrodes filling the device isolation gate channel trenches are formed on the semiconductor substrate having the gate insulating layer.

Preferably, a width of the recessed device isolation gate electrode is equal to or greater than a width of the recessed device gate electrode.

Preferably, an off bias is applied to the recessed device isolation gate electrode during operation to provide a device isolation function.

The line type active regions and the gate electrodes may be formed to have an intersection angle of 20° to 90°.

According to still another aspect of the present invention, there is provided a method of fabricating semiconductor device having line type active regions. The method comprises a step of forming a device isolation layer which defines the

line type active regions in a semiconductor substrate, wherein the active regions are formed to have a line type structure. Channel trenches which intersect the line type active regions are formed in the semiconductor substrate. A conformal gate insulating layer is formed on top surfaces of the line type active regions and inner surfaces of the channel trenches. Recessed device isolation gate electrodes filling the channel trenches and plan type device gate electrodes which are parallel to the recessed device isolation gate electrodes are formed on the semiconductor substrate having the gate insulating layer.

A width of the recessed device isolation gate electrode may be formed to be equal to or greater than a width of the plan type device gate electrode.

Preferably, an off bias is applied to the recessed device isolation gate electrode during operation to provide a device isolation function.

The line type active regions and the gate electrodes may be formed to have an intersection angle of  $20^\circ$  to  $90^\circ$ .

According to further still another aspect of the present invention, there is provided a method of fabricating semiconductor device having line type active regions. The method comprises a step of forming a device isolation layer which defines the line type active regions in a semiconductor substrate, wherein the active regions are formed to have a line type structure. A conformal gate insulating layer is formed on top surfaces of the line type active regions. Plan type device gate electrodes and plan type device isolation gate electrodes which are parallel to each other and intersect the line type active regions are formed on the semiconductor substrate having the gate insulating layer. Here, a width of the plan type device isolation gate electrode is formed to be greater than a width of the plan type device gate electrode.

Preferably, an off bias is applied to the plan type device isolation gate electrode during operation to provide a device isolation function.

The line type active regions and the gate electrodes may be formed to have an intersection angle of  $20^\circ$  to  $90^\circ$ .

According to further still another aspect of the present invention, there is provided a method of fabricating semiconductor device having line type active regions. The method comprises a step of forming a device isolation layer which defines the line type active regions in a semiconductor substrate, wherein the active regions are formed to have a line type structure. Channel trenches which intersect the line type active regions are formed in the semiconductor substrate. A conformal gate insulating layer is formed on top surfaces of the line type active regions and inner surfaces of the channel trenches. Recessed device gate electrodes filling the channel trenches and plan type device isolation gate electrodes which are parallel to the recessed device gate electrodes are formed on the semiconductor substrate having the gate insulating layer. Here, a width of the plan type device isolation gate electrode is formed to be greater than a width of the recessed device gate electrode.

Preferably, an off bias is applied to the plan type device isolation gate electrode during operation to provide a device isolation function.

The line type active regions and the gate electrodes may be formed to have an intersection angle of  $20^\circ$  to  $90^\circ$ .

#### BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

FIGS. 1A to 3A are plan views for illustrating a semiconductor device fabricating method according to an embodiment of the present invention;

FIGS. 1B to 3B are cross sectional views taken along section line I-I' of FIGS. 1A to 3A;

FIGS. 1C to 3C are cross sectional views taken along section line II-II' of FIGS. 1A to 3A;

FIGS. 4A to 6A are plan views for explaining a semiconductor device fabricating method according to another embodiment of the present invention;

FIGS. 4B to 6B are cross sectional views taken along section line III-III' of FIGS. 4A to 6A;

FIGS. 4C to 6C are cross sectional views taken along section line IV-IV' of FIGS. 4A to 6A;

FIGS. 7A to 9A are plan views for illustrating a semiconductor device fabricating method according to still another embodiment of the present invention;

FIGS. 7B to 9B are cross sectional views taken along section line V-V' of FIGS. 7A to 9A;

FIGS. 7C to 9C are cross sectional views taken along section line VI-VI' of FIGS. 7A to 9A;

FIGS. 10A to 12A are plan views for illustrating a semiconductor device fabricating method according to further still another embodiment of the present invention;

FIGS. 10B to 12B are cross sectional views taken along section line VII-VII' of FIGS. 10A to 12A; and

FIGS. 10C to 12C are cross sectional views taken along section line VIII-VIII' of FIGS. 10A to 12A.

#### DETAILED DESCRIPTION OF THE INVENTION

Now, exemplary embodiments of the present invention will be described in detail with reference to the accompanying drawings. The invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the concept of the invention to those skilled in the art. In the drawings, lengths and thicknesses of layers and regions and regions may be exaggerated for clarity. Like reference numerals in the drawings denote like devices, and thus their description will be omitted.

In the present invention, 'device gate' denotes a gate fabricated to perform read and write operations of a device, and 'device isolation gate' denotes a gate fabricated for performing a function of a device isolation layer. In addition, 'recessed gate electrode' denotes a gate electrode formed over a recessed gate channel having a three-dimensional structure, and 'plan type gate electrode' denotes a gate electrode formed over a plan type gate channel having a general two-dimensional structure.

FIGS. 1A to 3A are plan views for illustrating a semiconductor device fabricating method according to an embodiment of the present invention.

FIGS. 1B to 3B are cross sectional views taken along section line I-I' of FIGS. 1A to 3A.

FIGS. 1C to 3C are cross sectional views taken along section line II-II' of FIGS. 1A to 3A.

Referring to FIGS. 1A, 1B, and 1C, a device isolation layer **105** which defines active regions A is formed on an semiconductor substrate **100**, and the active regions A are formed to have a line type structure. The device isolation layer **105** may be formed by using a shallow trench isolation (STI) process. A portion of the line type active regions A in the semiconductor substrate is etched to form device gate channel trenches **110a** and device isolation gate channel trenches **110b** which are parallel to each other. At the same time, a portion of a top

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surface of the device isolation layer **105** may be etched. The channel trenches **110a** and **110b** are formed to intersect the line type active regions A. Next, by using a wet rinsing process using a rinsing solution, that is, a mixture solution of  $\text{NH}_4\text{OH}$ ,  $\text{H}_2\text{O}_2$ , and  $\text{H}_2\text{O}$  or a dry rinsing process using a chemical agent reacting with the semiconductor substrate **100**, lower corners of the channel trenches **110a** and **110b** are optionally rounded.

Referring to FIGS. 2A, 2B, and 2C, a conformal gate insulating layer **115** is formed on the semiconductor substrate on which the channel trenches **110a** and **110b** are formed. Preferably, the gate insulating layer **115** is formed by performing a thermal oxidation process on the semiconductor substrate. A gate electrode layer **127** filling the channel trenches **110a** and **110b** is formed on the semiconductor substrate having the gate insulating layer **115**. The gate electrode layer **127** may be formed of a polysilicon layer **120** and a metal silicide layer **125** which are sequentially stacked. The metal silicide layer **125** may be formed of tungsten silicide (WSi). A hard mask layer **130** is formed on the gate electrode layer **127**. The hard mask layer **130** may be formed of a silicon nitride layer.

Referring to FIGS. 3A, 3B, and 3C, the hard mask layer **130** is patterned to form hard mask patterns **130a** which intersect upper portions of the line type active regions A. By using the hard mask patterns **130a** as an etching mask, the metal silicide layer **125** and the polysilicon layer **120** are sequentially etched to form gate electrodes which intersect the upper portions of the line type active regions A. As the gate electrodes, recessed device gate electrodes G are formed over the device gate channel trenches **110a**, and recessed device isolation gate electrodes IG are formed over the device isolation gate channel trenches **110b**. At the same time, the gate insulating layer **115** may be etched. The recessed device gate electrodes G and the recessed device isolation gate electrodes IG are formed to have widths which are equal to widths of the device gate channel trenches **110a** and the device isolation gate channel trenches **110b**, respectively. This means that a width of the recessed gate electrode has a proportional relation with a length of gate channel. Therefore, if the width of the recessed gate electrode increases, a width of the lower channel trench also increases by the same width, so that the length of the gate channel increases.

Each of the recessed device gate electrodes G may be formed of a polysilicon pattern **120a** and a metal silicide pattern **125a** which are sequentially stacked. Each of the recessed device isolation gate electrodes IG may be formed of a polysilicon pattern **120b** and a metal silicide pattern **125b** which are sequentially stacked. Preferably, the widths W1 of the recessed device isolation gate electrodes IG are formed to be equal to or larger than the widths W2 of the recessed device gate electrodes G. Preferably, the line type active regions A and the gate electrodes G and IG are formed to have an intersection angle  $\alpha$  of  $20^\circ$  to  $90^\circ$ .

By using the hard mask patterns **130a** as a mask, impurity ions are implanted into the line type active regions A to form LDD source/drain regions **135**. Next, gate spacers **140** which surround sidewalls of the hard mask patterns **130a** and the gate electrodes G and IG are formed. The gate spacers **140** may be formed of a silicon nitride layer or a silicon oxide layer. By using the gate spacers **140** and the hard mask patterns **130a** as a mask, impurity ions are implanted into the line type active regions A to form high concentration source/drain regions **145**. After that, bit lines and capacitors are formed by using typical methods (not shown).

Write and read modes of the device fabricated according to embodiments of the present invention will now be described.

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If an off bias is applied to the recessed device isolation gate electrodes IG, and if high voltages are applied to the recessed device gate electrodes G and the bit lines, associated transistors are in ON state, channels for information charge are formed under the recessed device gate electrodes G, the information charge transmitted from the bit lines pass through the source region, the channel, and drain region into storage electrodes which are formed as lower electrodes of the capacitors, so that one bit of information is stored.

By applying the off bias to the recessed device isolation gate electrodes IG the information charge transmitted from the bit lines is prevented from flowing into source regions of adjacent transistors by preventing formation of the channels under the device isolation gate electrodes IG.

According to the present invention, channel length can be enlarged by using recessed channels under the recessed device isolation gate electrodes IG in comparison to a conventional technique, so that it is possible to improve the reliability of the device isolation function. In addition, the widths W1 of the recessed device isolation gate electrodes IG can be formed to be larger than the widths W2 of the recessed device gate electrodes G, so that it is possible to enhance the device isolation function. In addition, channel length under the recessed device gate electrodes G can be enlarged by using recessed device gate electrodes G, so that it is possible to prevent a short channel effect that could result from the high integration degree of the semiconductor device.

FIGS. 4A to 6A are plan views for illustrating a semiconductor device fabricating method according to another embodiment of the present invention.

FIGS. 4B to 6B are cross sectional views taken along section line III-III' of FIGS. 4A to 6A.

FIGS. 4C to 6C are cross sectional views taken along section line IV-IV' of FIGS. 4A to 6A.

Referring to FIGS. 4A, 4B, and 4C, a device isolation layer **205** which defines active regions A is formed on an semiconductor substrate **200**, and the active regions A are formed to have a line type structure. The device isolation layer **205** may be formed by using a shallow trench isolation (STI) process. A portion of the line type active regions A in the semiconductor substrate is etched to a device isolation gate channel trenches **210**. At the same time, a portion of a top surface of the device isolation layer **205** may be etched. The device isolation gate channel trenches **210** are formed to intersect the line type active regions A. Next, by using a wet rinsing process using a rinsing solution, that is, a mixture solution of  $\text{NH}_4\text{OH}$ ,  $\text{H}_2\text{O}_2$ , and  $\text{H}_2\text{O}$  or a dry rinsing process using a chemical agent reacting with the semiconductor substrate **200**, lower corners of the device isolation gate channel trenches **210** are optionally rounded.

Referring to FIGS. 5A, 5B, and 5C, a conformal gate insulating layer **215** is formed on the semiconductor substrate on which the device isolation gate channel trenches **210** are formed. Preferably, the gate insulating layer **215** is formed by performing a thermal oxidation process on the semiconductor substrate. A gate electrode layer **227** filling the device isolation gate channel trenches **210** is formed on the semiconductor substrate having the gate insulating layer **215**. The gate electrode layer **227** may be formed of a polysilicon layer **220** and a metal silicide layer **225** which are sequentially stacked. The metal silicide layer **225** may be formed of tungsten silicide (WSi). A hard mask layer **230** is formed on the gate electrode layer **227**. The hard mask layer **230** may be formed of a silicon nitride layer.

Referring to FIGS. 6A, 6B, and 6C, the hard mask layer **230** is patterned to form hard mask patterns **230a** which intersect upper portions of the line type active regions A. By

using the hard mask patterns **230a** as an etching mask, the metal silicide layer **225** and the polysilicon layer **220** are sequentially etched to form gate electrodes which intersect the upper portions of the line type active regions A. As the gate electrodes, recessed device isolation gate electrodes IG are formed over the device isolation gate channel trenches **210**, and plan type device gate electrodes G parallel to the recessed device isolation gate electrodes IG are formed. At the same time, the gate insulating layer **215** may be etched. The recessed device isolation gate electrodes IG are formed to have widths which are equal to widths of the device isolation gate channel trenches **210**. This means that a width of the recessed gate electrode has a proportional relation with a length of gate channel. Therefore, if the width of the recessed gate electrode increases, a width of the lower channel trench also increases by the same width, so that the length of the gate channel increases.

Each of the plan type device gate electrodes G may be formed of a polysilicon pattern **220a** and a metal silicide pattern **225a** which are sequentially stacked. Each of the recessed device isolation gate electrodes IG may be formed of a polysilicon pattern **220b** and a metal silicide pattern **225b** which are sequentially stacked. Preferably, the widths W3 of the recessed device isolation gate electrodes IG are formed to be equal to or larger than the widths W4 of the plan type device gate electrodes G. Preferably, the line type active regions A and the gate electrodes G and IG are formed to have an intersection angle  $\beta$  of 20° to 90°.

By using the hard mask patterns **230a** as a mask, impurity ions are implanted into the line type active regions A to form LDD source/drain regions **235**. Next, gate spacers **240** which surround sidewalls of the hard mask patterns **230a** and the gate electrodes G and IG are formed. The gate spacers **240** may be formed of a silicon nitride layer or a silicon oxide layer. By using the gate spacers **240** and the hard mask patterns **230a** as a mask, impurity ions are implanted into the line type active regions A to form a high concentration source/drain regions **245**. After that, bit lines and capacitors are formed by using typical methods (not shown).

Write and read modes of the device fabricated according to embodiments of the present invention will now be described. If an off bias is applied to the recessed device isolation gate electrodes IG, and if high voltages are applied to the plan type device gate electrodes G and the bit lines, associated transistors are in ON state, channels for information charge are formed under the plan type device gate electrodes G, the information charge transmitted from the bit lines passes through the source region, the channel, and drain region into storage electrodes which are formed as lower electrodes of the capacitors, so that a bit of information is stored.

By applying the off bias to the recessed device isolation gate electrodes IG, the information charge transmitted from the bit lines is prevented from flowing into source regions of adjacent transistors by preventing formation of current channels under the device isolation gate electrodes IG.

According to the present invention, channel length can be enlarged by using recessed channels under the recessed device isolation gate electrodes IG in comparison to a conventional technique, so that it is possible to improve the reliability of the device isolation function. In addition, the widths W3 of the recessed device isolation gate electrodes IG can be formed to be larger than the widths W4 of the plan type device gate electrodes G, so that it is possible to enhance the device isolation function.

FIGS. 7A to 9A are plan views for illustrating a semiconductor device fabricating method according to still another embodiment of the present invention.

FIGS. 7B to 9B are cross sectional views taken along section line V-V' of FIGS. 7A to 9A.

FIGS. 7C to 9C are cross sectional views taken along section line VI-VI' of FIGS. 7A to 9A.

Referring to FIGS. 7A, 7B, and 7C, a device isolation layer **305** which defines active regions A is formed on a semiconductor substrate **300**. Here, the active regions A are formed to have a line type structure. The device isolation layer **305** may be formed by using a shallow trench isolation (STI) process.

Referring to FIGS. 8A, 8B, and 8C, a gate insulating layer **315** is formed on the line type active regions A. Preferably, the gate insulating layer **315** is formed by performing a thermal oxidation process on the semiconductor substrate. A gate electrode layer **327** is formed on the semiconductor substrate having the gate insulating layer **315**. The gate electrode layer **327** may be formed of a polysilicon layer **320** and a metal silicide layer **325** which are sequentially stacked. The metal silicide layer **325** may be formed of tungsten silicide (WSi). A hard mask layer **330** is formed on the gate electrode layer **327**. The hard mask layer **330** may be formed of a silicon nitride layer.

Referring to FIGS. 9A, 9B, and 9C, the hard mask layer **330** is patterned to form hard mask patterns **330a** which intersect upper portions of the line type active regions A. By using the hard mask patterns **330a** as an etching mask, the metal silicide layer **325** and the polysilicon layer **320** are sequentially etched to form gate electrodes which are parallel to each other and intersect the upper portions of the line type active regions A. The gate electrodes are formed of plan type device gate electrodes G and plan type device isolation gate electrodes IG, and widths D1 of the plan type device isolation gate electrodes are formed to be larger than widths D2 of the plan type device gate electrodes G. At the same time, the gate insulating layer **315** may be etched. Each of the plan type device gate electrodes G may be formed of a polysilicon pattern **320a** and a metal silicide pattern **325a** which are sequentially stacked. Each of the plan type device isolation gate electrodes IG may be formed of a polysilicon pattern **320b** and a metal silicide pattern **325b** which are sequentially stacked. Preferably, the line type active regions A and the gate electrodes G and IG are formed to have an intersection angle  $\gamma$  of 200 to 90°.

By using the hard mask patterns **330a** as a mask, impurity ions are implanted into the line type active regions A to form LDD source/drain regions **335**. Next, gate spacers **340** which surround sidewall of the hard mask patterns **330a** and the gate electrodes G and IG are formed. The gate spacers **340** may be formed of a silicon nitride layer or a silicon oxide layer. By using the gate spacers **340** and the hard mask patterns **330a** as a mask, impurity ions are implanted into the line type active regions A to form a high concentration source/drain regions **345**. After that, bit lines and capacitors are formed by using typical methods (not shown).

Write and read modes of the device fabricated according to embodiments of the present invention will now be described. If an off bias is applied to the plan type device isolation gate electrodes IG, and if high voltages are applied to the plan type device gate electrodes G and the bit lines, associated transistors are in an ON state, channels for information charge are formed under the plan type device gate electrodes G, the information charge transmitted from the bit lines pass through the source region, the channel, and drain region into storage electrodes which are formed as lower electrodes of the capacitors, so that a bit of information is stored.

By applying the off bias to the plan type device isolation gate electrodes IG, the information charge transmitted from the bit lines is prevented from flowing into source regions of

adjacent transistors by preventing formation of the channels under the device isolation gate electrodes IG.

According to the present invention, since the widths D1 of the plan type device isolation gate electrodes IG are formed to be larger than the widths D1 of the plan type device gate electrodes G, channel length can be enlarged in comparison to a conventional technique, so that so that it is possible to improve the reliability of the device isolation function.

FIGS. 10A to 12A are plan views for illustrating a semiconductor device fabricating method according to further still another embodiment of the present invention.

FIGS. 10B to 12B are cross sectional views taken along section line VII-VII' of FIGS. 10A to 12A.

FIGS. 10C to 12C are cross sectional views taken along section line VIII-VIII' of FIGS. 10A to 12A.

Referring to FIGS. 10A, 10B, and 10C, a device isolation layer 405 which defines active regions A is formed on a semiconductor substrate 400. Here, the active regions A are formed to have a line type structure. The device isolation layer 405 may be formed by using a shallow trench isolation (STI) process. A portion of the line type active regions A in the semiconductor substrate is etched to a device gate channel trenches 410. At the same time, a portion of a top surface of the device isolation layer 405 may be etched. The device gate channel trenches 410 are formed to intersect the line type active regions A. Next, by using a wet rinsing process using a rinsing solution, that is, a mixture solution of  $\text{NH}_4\text{OH}$ ,  $\text{H}_2\text{O}_2$ , and  $\text{H}_2\text{O}$  or a dry rinsing process using a chemical agent reacting with the semiconductor substrate 400, lower corners of the device gate channel trenches 410 are optionally rounded. Referring to FIGS. 11A, 11B, and 11C, a conformal gate insulating layer 415 is formed on the semiconductor substrate on which the device gate channel trenches 410 are formed. Preferably, the gate insulating layer 415 is formed by performing a thermal oxidation process on the semiconductor substrate. A gate electrode layer 427 filling the device gate channel trenches 410 is formed on the semiconductor substrate having the gate insulating layer 415. The gate electrode layer 427 may be formed of a polysilicon layer 420 and a metal silicide layer 425 which are sequentially stacked. The metal silicide layer 425 may be formed of tungsten silicide (WSi). A hard mask layer 430 is formed on the gate electrode layer 427. The hard mask layer 430 may be formed of a silicon nitride layer.

Referring to FIGS. 12A, 12B, and 12C, the hard mask layer 430 is patterned to form hard mask patterns 430a which intersect upper portions of the line type active regions A. By using the hard mask patterns 430a as an etching mask, the metal silicide layer 425 and the polysilicon layer 420 are sequentially etched to form gate electrodes which intersect the upper portions of the line type active regions A. As the gate electrodes, recessed device gate electrodes G are formed over the device gate channel trenches 410, and plan type device isolation gate electrodes IG parallel to the recessed device gate electrodes G are formed. Widths D3 of the plan type device isolation gate electrodes IG are formed to be larger than widths D4 of the recessed device gate electrodes G. At the same time, the gate insulating layer 415 may be etched. The recessed device gate electrodes G are formed to have widths which are equal to widths of the device gate channel trenches 410.

Each of the recessed device gate electrodes G may be formed of a polysilicon pattern 420a and a metal silicide pattern 425a which are sequentially stacked. Each of the plan type device isolation gate electrodes IG may be formed of a polysilicon pattern 420b and a metal silicide pattern 425b which are sequentially stacked. Preferably, the line type

active regions A and the gate electrodes G and IG are formed to have an intersection angle  $\delta$  of  $20^\circ$  to  $90^\circ$ .

By using the hard mask patterns 430a as a mask, impurity ions are implanted into the line type active regions A to form LDD source/drain regions 435. Next, gate spacers 440 which surround sidewall of the hard mask patterns 430a and the gate electrodes G and IG are formed. The gate spacers 440 may be formed of a silicon nitride layer or a silicon oxide layer. By using the gate spacers 440 and the hard mask patterns 430a as a mask, impurity ions are implanted into the line type active regions A to form a high concentration source/drain regions 445. After that, bit lines and capacitors are formed by using typical methods (not shown).

Write and read modes of the device fabricated according to embodiments of the present invention will now be described. If an off bias is applied to the plan type device isolation gate electrodes IG, and if high voltages are applied to the recessed device gate electrodes G and the bit lines, associated transistors are in ON state, channels for information charge are formed under the recessed device gate electrodes G, the information charge transmitted from the bit lines pass through the source region, the channel, and drain region into storage electrodes which are formed as lower electrodes of the capacitors, so that a bit of information is stored.

By applying the off bias to the plan type device isolation gate electrodes IG, the information charge transmitted from the bit lines is prevented from flowing into source regions of adjacent transistors by preventing formation of the channels under the device isolation gate electrodes IG.

According to the present invention, the widths D3 of the plan type device isolation gate electrodes IG are formed to be larger than the D4 of the recessed device gate electrodes G, channel length can be enlarged in comparison to a conventional technique, so that it is possible to improve reliability of the device isolation function. In addition, channel length under the recessed device gate electrodes G can be enlarged by using recessed device gate electrodes G, so that it is possible to prevent a short channel effect from occurring although the semiconductor device is highly integrated.

Now, returning to FIGS. 3A, 3B and 3C, a semiconductor device according to an embodiment of the present invention will be again described.

Referring to FIGS. 3A, 3B, and 3C, the semiconductor device includes a device isolation layer 105 which defines active regions A in a semiconductor substrate 100. Preferably, the device isolation layer 105 has a shallow trench isolation (STI) structure. Gate electrodes which are parallel to each other and intersect the line type active regions A are disposed on the semiconductor substrate 100. Here, the gate electrodes are constituted of device gate electrodes G and recessed device isolation gate electrodes IG. The device gate electrode G may be a plan type device gate electrode or a recessed device gate electrode. In the present embodiment, the recessed device gate electrodes are exemplified. The recessed device gate electrodes G may be constituted of a polysilicon pattern 120a and a tungsten silicide pattern 125a which are sequentially stacked. In addition, the recessed device isolation gate electrodes IG may be a polysilicon pattern 120b and a tungsten silicide pattern 125b which are sequentially stacked.

Widths W1 of the recessed device isolation gate electrodes IG may be equal to or greater than widths W2 of the device gate electrodes G. Preferably, an off bias is applied to the recessed device isolation gate electrodes IG. An intersection angle  $\alpha$  of the line type active regions A and the gate electrodes G and IG may be in a range of  $20^\circ$  to  $90^\circ$ .

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Device isolation gate channel trenches **110b** are disposed under the recessed device isolation gate electrodes IG in the semiconductor substrate. In addition, in a case where the device gate electrodes G are recessed device gate electrodes, device gate channel trenches **110a** may be disposed under the recessed device gate electrodes G in the semiconductor substrate. A conformal gate insulating layer **115** may be disposed between the line type active regions A and the gate electrodes G and IG. Hard mask patterns **130a** may be disposed over the gate electrodes G and IG. LDD source/drain regions **135** may be disposed between the gate electrodes G and IG in the line type active regions A. Gate spacers **140** which surround sidewalls of the hard mask patterns **130a** and the gate electrodes G and IG may be included. The gate spacers **140** may be a silicon nitride layer or a silicon oxide layer. High concentration source/drain regions **145** may be disposed between the adjacent gate spacers **140** in the line type active regions A.

Now, returning to FIGS. **9A**, **9B** and **9C**, a semiconductor device according to another embodiment of the present invention will be again described.

Referring to FIGS. **9A**, **9B**, and **9C**, the semiconductor device includes a device isolation layer **305** which defines active regions A in a semiconductor substrate **300**. Preferably, the device isolation layer **305** has a shallow trench isolation (STI) structure. Gate electrodes which are parallel to each other and intersect the line type active regions A are disposed on the semiconductor substrate **300**. Here, the gate electrodes are constituted of device gate electrodes G and plan type device isolation gate electrodes IG. Here, widths **D1** of the plan type device isolation gate electrodes IG are formed to be larger than widths **D2** of the device gate electrodes G. The device gate electrodes G may be a plan type device gate electrode or a recessed device gate electrode. In the embodiment, the plan type device gate electrodes are exemplified. The plan type device gate electrodes G may be a polysilicon pattern **320a** and a tungsten silicide pattern **325a** which are sequentially stacked. In addition, the plan type device isolation gate electrodes IG may be a polysilicon pattern **320b** and a tungsten silicide pattern **325b** which are sequentially stacked.

Preferably, an off bias is applied to the plan type device isolation gate electrodes IG. An intersection angle  $\gamma$  of the line type active regions A and the gate electrodes G and IG may be in a range of  $20^\circ$  to  $90^\circ$ . In a case where the device gate electrodes G are recessed device gate electrodes, device gate channel trenches may be disposed under the recessed device gate electrodes in the semiconductor substrate. A conformal gate insulating layer **315** may be disposed between the line type active regions A and the gate electrodes G and IG. Hard mask patterns **330a** may be disposed over the gate electrodes G and IG. LDD source/drain regions **335** may be disposed between the gate electrodes G and IG in the line type active regions A. Gate spacers **340** which surround sidewalls of the hard mask patterns **330a** and the gate electrodes G and IG may be disposed. The gate spacers **340** may be a silicon nitride layer or a silicon oxide layer. High concentration source/drain regions **345** may be disposed between the adjacent gate spacers **340** in the line type active regions A.

According to the present invention, line type active regions are formed, and device isolation gate electrodes which are parallel to each other and intersect the line type active regions are formed. Here, the device isolation gate electrodes are constituted of recessed device isolation gate electrodes, and channel length can increase in comparison to a conventional technique by using recessed channels under the recessed device isolation gate electrodes, so that it is possible to improve reliability to a device isolation function. Alternately,

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tively, the device isolation gate electrodes are constituted of plan type device isolation gate electrodes of which a width is formed to be larger than a width of the device gate electrode, so that it is possible to enhance the device isolation function.

Accordingly, it is possible to implement a semiconductor device having high integration degree and excellent device characteristics by using the line type active regions and the device isolation gates.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made herein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

**1.** A semiconductor device, comprising:

a device isolation layer which defines line type active regions in a semiconductor substrate; and

gate electrodes which are disposed over the semiconductor substrate to be parallel to each other and obliquely intersect the line type active regions,

wherein the gate electrodes include both a device gate electrode and a recessed device isolation gate electrode, wherein the recessed device isolation gate electrode has an insulating layer between the line type active regions and thereof.

**2.** The semiconductor device according to claim **1**, wherein the device gate electrode is one of a flat bottom type device gate electrode and a recessed device gate electrode.

**3.** The semiconductor device according to claim **2**, wherein a width of the recessed device isolation gate electrode is equal to or greater than a width of the device gate electrode.

**4.** The semiconductor device according to claim **1**, wherein an off bias is applied to the recessed device isolation gate electrode during operation to provide a device isolation function.

**5.** The semiconductor device according to claim **1**, wherein an intersection angle of the line type active regions and the gate electrodes is in a range of  $20^\circ$  to  $90^\circ$ .

**6.** The semiconductor device according to claim **1**, wherein the device isolation layer has a shallow trench isolation (STI) structure.

**7.** The semiconductor device according to claim **1**, wherein a conformal gate insulating layer is disposed between the line type active regions and the gate electrodes.

**8.** The semiconductor device according to claim **1**, wherein each of the gate electrodes comprises a polysilicon pattern and a tungsten silicide pattern which are sequentially stacked.

**9.** The semiconductor device according to claim **1**, wherein the insulating layer is directly in contact with the recessed device isolation gate electrode.

**10.** The semiconductor device according to claim **9**, wherein the insulating layer is conformal.

**11.** A semiconductor device fabricating method, comprising steps of:

forming a device isolation layer which defines active regions in a semiconductor substrate, the active regions having a line type structure;

forming channel trenches which intersect the line type active regions in the semiconductor substrate;

forming a conformal gate insulating layer on top surfaces of the line type active regions and inner surfaces of the channel trenches; and

forming recessed device isolation gate electrodes filling the channel trenches and flat bottom type device gate electrodes which are parallel to the recessed device iso-

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lation gate electrodes on the semiconductor substrate having the gate insulating layer.

**12.** The semiconductor device fabricating method according to claim **11**, wherein a width of the recessed device isolation gate electrode is formed to be equal to or greater than a width of the flat bottom type device gate electrode.

**13.** The semiconductor device fabricating method according to claim **11**, wherein an off bias is applied to the recessed device isolation gate electrode during operation to provide a device isolation function.

**14.** The semiconductor device fabricating method according to claim **11**, wherein an intersection angle of the line type active regions and the gate electrodes is in a range of 20° to 90°.

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**15.** The semiconductor device fabricating method according to claim **11**, wherein the device isolation layer is formed to have a shallow trench isolation (STI) structure.

**16.** The semiconductor device fabricating method according to claim **11**, wherein the gate insulating layer is formed using a thermal oxidation process.

**17.** The semiconductor device fabricating method according to claim **11**, wherein each of the gate electrodes is formed of a polysilicon pattern and a tungsten silicide pattern which are sequentially stacked.

**18.** The semiconductor device fabricating method according to claim **11**, wherein the recessed device isolation gate electrodes is directly in contact with the conformal gate insulating layer in the channel trenches.

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